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ORIGINAL ARTICLES.

I.—The Petrography of Arran.

3. Pitchstone Xenoliths in Basalt Dyke, Dippin, Arran.[1]

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THE phenomenon of which this paper treats occurs in a basalt dyke exposed in a small quarry by the roadside north-east of Dippin, near the twelfth milestone from Brodick. This dyke runs from north-west to south-east, and is intrusive into the great teschenite (or crinanite) sill of Dippin. It is probably the one referred to in the Geological Survey Memoir on North Arran, South Bute, and the Cumbraes (1903), p. 119. It averages 12 feet in thickness, although it is extremely irregular, owing perhaps to the difficulty experienced in penetrating the tough, coarse, massive rock of the sill. The contacts are not plane, but abut against the crinanite in a very intricate manner, sometimes along vertical or horizontal joints, sometimes along irregular surfaces unconnected with jointing. Both contacts show thin films of tachylyte, which, as the rock is quarried, are left adhering to the irregular surfaces of the sill rock. Another dyke-like mass, 1 foot thick, is seen in the same quarry, and is doubtless an offshoot from the larger dyke.

Within a foot of the northern contact of the larger dyke there are found enclosed several lumps of brown and black glassy rocks containing a few large white crystals of felspar. These lumps range from 1 to 3 inches in diameter, and are each surrounded by a thin film of tachylyte, while small clots of a black glass are to be found in their vicinity. Other xenoliths found near by consist of a medium-grained crystalline rock resembling the crinanite of the Dippin sill. These are larger than the glassy xenoliths and are quite evidently affected by heat. They are also surrounded by a skin and some ies clots of tachylyte.

The Dyke.—The dyke belongs to a distinctive group of the Tertiary north-west dykes, which appears to be abundantly distributed about the Clyde Estuary. These dykes have frequently been called 'basaltic andesite' or 'andesitic basalt', and are distinguished by containing beautifully fresh phenocrysts of anorthite or bytownite, in a ground-mass composed of laths of labradorite, augite frequently intergrown with enstatite or hypersthene, and an abundant mesostasis

[1] The first two papers of this series appeared in the Geol. Mag., Dec. V, Vol. X, pp. 305–9, 1913.

of dark glass. From their abundance in the island of Great Cumbrae, situated in the Firth of Clyde, it is proposed to distinguish them as the *Cumbrae* type of basalt. The Tynemouth dyke of the North of England appears to be an outlying member of the same series.

In thin section the rock from the centre of the dyke shows small but rather numerous phenocrysts of plagioclase felspar which are occasionally euhedral, but are more often worn and corroded into curious irregular shapes. Whatever the shape, all the crystals possess a narrow marginal zone of different composition orientated similarly to the main mass. The transition between the two parts is usually quite sharp. The measurement of extinction angles shows that the crystals are bytownite (Ab_1An_3) with marginal labradorite. There are also a few phenocrysts of fresh enstatite, showing a good positive biaxial figure in basal section; and fewer still of a yellowish augite. The ground-mass is composed of zonal labradorite laths, intermixed with prismoids of augite and grains of iron-ore, with an abundant mesostasis apparently of a felspathic substance, crowded with black hair-like microlites, and probably representing a devitrified glass.

This rock is an andesitic basalt or basaltic andesite generally similar to the Tynemouth and Cleveland dykes of the North of England. Other dykes of the same character, with slight variations in texture, amount of glass, or abundance of phenocrysts, occur in the vicinity, cutting the Dippin sill and the adjacent Triassic sandstones.

Traced towards the margin of the dyke the rock becomes denser, and contains fewer and smaller felspar phenocrysts. A specimen taken 3 inches from the margin shows a beautiful variolitic texture in thin section. The felspars of the ground-mass are reduced to the size of large microlites, and are arranged in irregular radiating bundles or sheaves which involve numerous long prisms of augite and grains of iron-ore.

At the actual margin the rock is tachylytic for a thickness of ¼ inch. In thin section the glass is dark, opaque, and almost structureless, with only a few obscure microlites. It contains numerous small spherical amygdales of calcite, and a few small phenocrysts of labradorite with the usual rounded or irregular outlines indicating magmatic corrosion.

The Xenoliths.—The great majority of the xenoliths are of pitchstone. In thin section the bulk of this rock is seen to consist of a pure, almost colourless glass, in which hair-like microlites are aggregated into clots or patches, leaving large areas of glass absolutely free from microlites. The phenocrysts are of euhedral quartz, orthoclase, and andesine (Ab_5An_3). The effects of the heat to which this rock has been subjected are striking. Of the three principal minerals orthoclase has suffered the most, andesine much less, and quartz hardly at all. The orthoclase in all cases shows some degree of fusion, which has occurred around the margins and along the cleavages, producing a yellow or greyish glass which contrasts with the lighter glass of the ground-mass. The resulting shapes of the crystals are highly irregular; occasionally the crystal

is separated into two or three pieces by areas of fusion; but in extreme cases the crystal is represented by a 'ghost' in greyish glass, in which only minute shreds of the original orthoclase have survived.

The andesine crystals have apparently only suffered a little softening on the margins and fissuring in the interiors. The quartz has suffered least of all, as the crystals are only fractured. The fact that the broken pieces have occasionally floated away from one another is evidence that the glass of the pitchstone was rendered completely liquid by the degree of heat to which it was subjected.

Each xenolith is surrounded by a skin and sometimes clots of a black glass, which was at first regarded as a tachylyte of the same nature as that on the margins of the dyke. A thin section, however, shows that this material is really a colourless glass which is darkened by numberless lines, streaks, and patches of black dots, arranged with a perfect fluxional structure. The glass contains the same set of phenocrysts as the above-described pitchstone, but much smaller and fewer. Under a high-power objective the black dots which darken the glass are made out to be small, perfectly euhedral, hexagonal tablets of hæmatite, the larger ones translucent and of a blood-red colour.

The difference between this rock and the pitchstone it envelops may be explained thus: the xenoliths have not only been perfectly fused, but the pitchstone glass has intermingled to some extent with the more basic glass of the basalt in which the xenoliths were carried up, the admixture of basalt glass resulting in the formation of swarms of hæmatite microlites. The flow-structure may have been imparted by a rolling motion of the xenoliths, due to differential velocity of the central and marginal parts of the basalt dyke during intrusion. The xenoliths are found within one foot of the margin, where movement would be retarded by cooling and viscosity on the marginal side, whilst proceeding at a faster rate in the more liquid interior.

Conclusions.—The behaviour of the phenocrysts in the pitchstone xenoliths under the influence of heat gives some clue as to the temperature of the basaltic magma in which they were immersed. The orthoclase was partially or wholly fused to a yellow or grey glass, andesine showed signs of softening around the edges, whilst quartz simply suffered some degree of fracturing. The most trustworthy estimates of the fusion-points of rock-forming minerals have been made by A. L. Day and his collaborators in the Geophysical Laboratory at Washington.[1] That of quartz (or rather silica, since quartz is unstable above 800° C.) is given as 1,625° C.; of oligoclase-andesine (Ab_2 An_1) as 1,375° C. For orthoclase, however, we have to rely on the estimates of other experimenters.[2] The average of seven closely accordant estimates by Joly and Cusack, and Doelter, is 1,170° C. These figures are as would be expected from the effects produced by heat on these minerals. Orthoclase, which fuses at 1,170° C., has been converted into glass; andesine,

[1] Clarke, *Data of Geochemistry*, 2nd Ed., U.S. Geol. Surv., Bull. 491, p. 279, 1911.

[2] Iddings, *Igneous Rocks*, vol. i, p. 85, 1909.

fusing in the neighbourhood of 1,375° C., has barely been affected; quartz, fusing at 1,625° C., has only suffered fracturing. We may therefore conclude that the temperature of the basaltic magma during intrusion was between 1,170° C. and 1,375° C., excluding, as seems legitimate, any chemical reaction between orthoclase and the pitchstone glass. The ordinary basalt lava is fusible at about 1,100° C., and this is perhaps the ordinary temperature of emission at a volcano, although Daly believes temperatures of 1,200° C., or even 1,300° C., may prevail in the great volcanoes of Hawaii at periods of intense activity.[1] The fusion of minerals and even rocks has been observed in basaltic magmas by Lacroix and others.[2] Independent evidence of high temperature upon intrusion in the case of the dyke in question is afforded by its tachylytic selvages. These are due to very rapid marginal cooling, and the rate of cooling depends directly on the difference between the temperature of the country rock and of the magma.

The occurrence of xenoliths of pitchstone in a Cumbrae type of basalt, which itself intrudes a sill of teschenite or crinanite, affords useful evidence as to the relative ages of these three groups of intrusive rocks. A pitchstone dyke with a felsitic centre cuts the Dippin crinanite near Torr an Loisgte, about 1½ miles north-west of the quarry in which the xenoliths are found.[3] This dyke trends in a north-west direction, and would therefore, if produced, appear in the vicinity of the quarry, beneath the crinanite sill. It is possible that fragments of this dyke have been brought up by the basaltic magma. The sequence of the three types in time is clearly, first the crinanite sill, then the pitchstone, and finally the Cumbrae basalt. Similar evidence from other parts of the island goes to show that the Cumbrae basalts were one of the latest manifestations of igneous activity in Arran, if not the latest.

II.—A New Variety of the Ammonite *Cœloceras Davæi*, from the Lower Lias, Dorset.

By Wyatt Wingrave, M.D.

(PLATE VIII.)

QUENSTEDT[4] described three distinct varieties of *Ammonites Davæi*, with nine illustrations. They all belonged to the γ zone of Lower Lias:—

1. *Ammonites Davæi*, whose tubercles are somewhat clavate and with unsymmetrical prorsiradiate ribs.
2. *A. Davæi enodis* is continental. It is a small specimen without tubercles, with fine symmetrical and prorsiradiate ribs.
3. *A. Davæi nodosissimus* is also continental. This variety shows nine large bullate tubercles on each whorl, with close, fine, and symmetrically disposed flexiradiate ribs.

[1] *Igneous Rocks and their Origin*, 1914, p. 212.
[2] Lacroix, *Les Enclaves des Roches Volcaniques*, 1893, pp. 563–5.
[3] A. Scott, "Pitchstones of South Arran": Trans. Geol. Soc. Glasgow, vol. xv, pt. i, p. 22, 1914.
[4] Quenstedt, *Die Ammoniten des Schwäbischenjura*, 1885.

G. F. Strawson, photo.

COELOCERAS DAVOEI, RECTIRADIATUM, *var. nov.*

Lower Lias. Golden Cap, Dorset.

Hitherto the first variety only has been described as of English source. Last year, on following the eastward continuation of the Green Ammonite Beds to Golden Cap several fragments of *Davæi* were found in the Red Band. One of these supplies a nearly complete specimen, which does not conform to either of the above varieties.

It differs from 1 and 3 in several respects. The ribs are of finer texture, more numerous, never bifurcate, symmetrical in size and spacing, rectiradiate and showing no tendency whatever to a forward inclination, except the last few ribs near the aperture. In *C. Davæi* the ribs are strongly prorsiradiate, unsymmetrical, and often bifurcate. The tubercles are much more numerous than in the orthodox *Davæi*. They abruptly commence at the beginning of the penultimate whorl, and apparently adorn each rib as far as the innermost whorls can be identified. In shape they are somewhat clavate, but not so prominent as in the ordinary *Davæi*.

In the photograph several of the ribs on the outer whorls appear to indicate a tendency to tuberculation or 'flaring'; this is due to unremoved matrix. The suture has not yet been exposed, although an area of an inch or more of test was removed from the outer whorl near its termination, showing that the body-chamber, like other forms of *Davæi*, is evidently a long one occupying more than one whorl.

The degree of involution is very slight, barely more than contact. Nearly the whole of the test is intact, and shows the characteristic russet colour of the matrix. (Plate VIII.)

Suggested name.—*Cœloceras Davæi*, var. *rectiradiatum* (var. nov.).

Morphological Details.

Size.—Diameter 80 mm.

Whorls.—Very slightly involute, polygyral (6), uncompressed, symmetrical increase in size and shape.

Ribs.—Numerous, single (never bifurcated), rectiradiate, shallow, regular interspaced, uninterrupted at venter.

Tubercles.—Numerous, small, clavate, on all the inner whorls, but outer whorl undecorated, non-septate.

Umbilicus.—Shallow, open (concentrum- and latumbilicate).

Venter.—Convex, costæ uninterrupted.

Suture.—Not exposed.

Distribution (source).—Red Band, Green Ammonite Beds, Lower Lias: Golden Cap, Dorset.

Stratigraphy.

This specimen came from the "Red Band" of the Green Ammonite Beds, which at Golden Cap near Seatown forms its base, and is convenient of access from the beach. Below it is the well-marked "White Band", each having its attendant beds of clay. Here the limestone Red Band is scarcely 1 foot in thickness and occurs as a single layer, but Mr. Lang is of the opinion that further west it is probably double owing to weathering influences.[1] These beds yield a fair supply of Ammonites, chiefly in fragments among the clays.

[1] W. D. Lang, "Geology of Charmouth Cliffs": Proc. Geol. Assoc., vol. xxv, pt. v, 1914.

Above are *oistoceras*, *T. Loscombei*, below are *latecosta* and varieties of *liparoceras*. The Red Band itself yields *Davœi* and various *striata*.

Complete specimens are confined to the limestone bands, for in the clays they are much mixed and often only as fragments, casts, and moulds.

Oppel included practically the whole of the Green Ammonite Beds in his *Davœi* zone; but in England this should be restricted to the Red Band, although fragments of *Davœi* are often found in the clays several feet from the Red Limestone.

For the excellent photograph the writer is indebted to Mr. G. F. Strawson.

III.—The Crystalline Rock Areas of the Piémontese Alps. I. Southern and Western Piémont.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

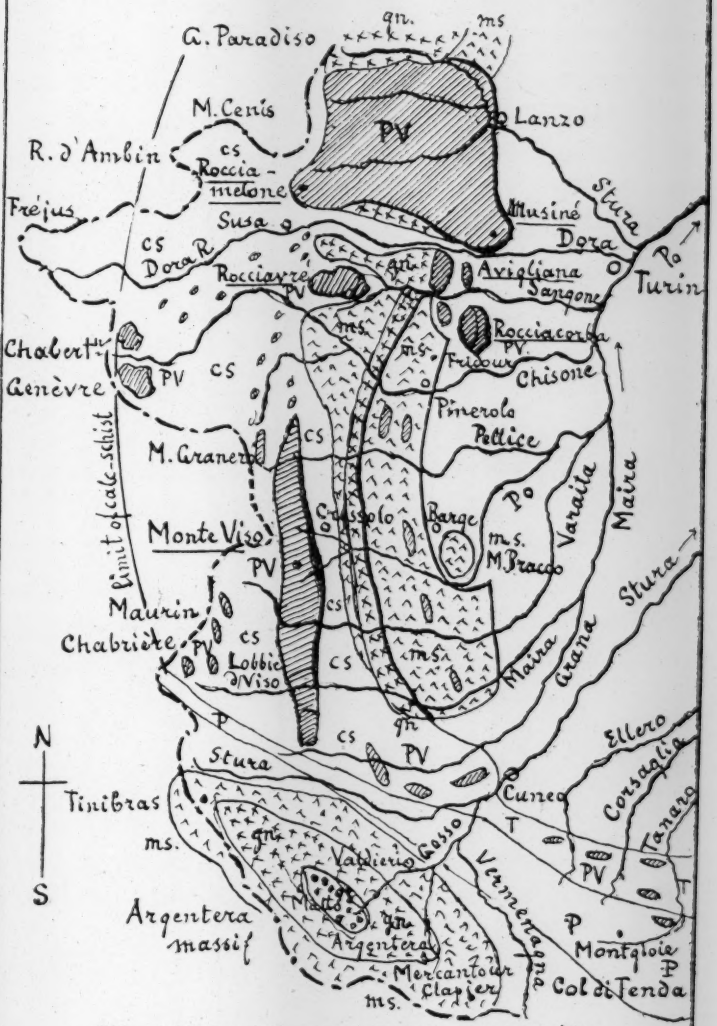
Introductory.

In continuation of the preceding paper (Geol. Mag., April, p. 156) which, as a preliminary to the present one, outlined the new classification of the crystalline rock formations and the nomenclature of the pietre verdi of the Piémontese Alps, I now propose to briefly describe the principal pietre verdi areas with which I became familiar during a long stay on repeated occasions in Turin. This city, apart from its rich collections of the rocks and minerals of the Piémontese Alps, is a most central and convenient starting-point for examining the different valleys debouching into the plain of the Po from the magnificent crescent formed by the Maritime, Cottian, Grajan, and Pennine Alps, which, as seen from Turin, afford by far the most extensive and fascinating Alpine panorama in Italy.

The principal pietre verdi areas lie more especially along or near the inner belt or concave eastern edge of the Alpine crescent, and include, among others, the following mountains and valleys which will be referred to in this and a subsequent paper, and all of which form part of the watershed of the Po:—

Range.	Mountain.	Altitude.	Valleys.
		m.	
Maritime	Montgioie	2,836	Bormida, Tanaro, Corsaglia, Ellero, Vermenagna.
,,	Argentera	3,397	Gesso, Stura di Cuneo.
Cottian	Monte Viso	3,843	Grana, Maira, Varaita, Po, Pellice, Germanasca.
,,	Rocciavré	2,778	Chisone, Sangone.
Grajan	Rocciamelone	3,537	Dora Riparia (Susa Valley).
,,	Ciamarella	3,876	Stura di Lanzo: Usseglio, Balme, and Grande Valleys.
,,	Gran Paradiso	4,081	Orco, Soana.
,,	Grivola	3,961	Dora Baltea (Aosta Valley), Cogne, Valsavaranche.
,,	Mte. Emilius	3,559	Dora Baltea, Buthier, Valpelline.
Pennine	Mte. Rosa	4,636	(Ivrea Belt) Chiusella, Dora Baltea, Tourmanche, Gressonay, Cervo, Sesia.

Fig. 1, SKETCH-MAP
of Crystalline Rock Areas in Piédmontese Alps
(Southern and Western Piédmont.)



PV = pietre-verdi; gn = gneiss; gr = granite;
ms = mica-schist; cs = calc-schist; P = Permian;
T = Trias.

Scale 1 : 1,100,000. Del. D.R.P.

Of the mountains enumerated, the Argentera and Gran Paradiso massifs, with a gneiss nucleus in each case, are the only ones which have preserved their original ellipsoidal, dome-shaped outlines, while most of the others, lying in the calc-schist and pietre verdi areas, are conspicuous pyramids whose precipitous flanks, pre-eminently those of Monte Viso and Grivola, were chiselled probably quite as much by atmospheric as by fluviatile or glacially abrasive action. The six principal pietre verdi areas, of which the first three will be dealt with in the present and the other three in a subsequent paper, are as follows:—

I. *In Southern and Western Piémont:* (1) the Maritime Alps; (2) Monte Viso; (3) the Dora Riparia, Sangone, and Avigliana group.

II. *In Northern Piémont:* (4) the Lanzo Valleys; (5) the Dora Baltea or Aosta Valley; (6) the Lanzo, Ivrea, and Val Sesia group.

I. The Maritime Alps Group. (Fig. 1.)

1. *Montgioie Range.*—The pietre verdi area between the Ellero, Corsaglia, Tanaro, and Bormida Valleys on the north side of the Montgioie range derives special interest from the fact that the deposits occur in the Permian and Triassic crystalline formations, already described in a previous paper,[1] while further east, towards Savona and near Voltri in Liguria, similar deposits are intercalated in Triassic schists, and further west, along the French frontier, they appear in the calc-schist formation. Proof is thus afforded that the pietre verdi are not confined to any particular horizon, but are associated with both Mesozoic and Palæozoic formations. Some of the pietre verdi deposits on the northern slopes of the Montgioie range were already mentioned by Zaccagna[2]; but their number and extent has more recently been considerably increased by Franchi,[3] who regards all the pietre verdi of the Ligurian, Maritime, and Cottian Alps as links in the same Mesozoic horizon.

The pietre verdi deposits between the Ellero, Tanaro, and Bormida Valleys, extending for about 30 kilometres along the lower hills from Villanova to Millesimo, are composed chiefly of lenticular masses of serpentinous, diabasic, and euphoditic rocks, the latter two largely altered to amphibolites and prasinites, all associated with Triassic crystalline and dolomitic limestone, in the Bormida valleys also with Permian schist, as already mentioned. In these, as also in the Lower Trias, occur frequent outcrops of laminated porphyric rock and masses of amphibolic schist often epidotic and garnetiferous, with abundant glaucophane.[4]

West of the Montgioie range, in the border zone of the Maritime and Cottian Alps, and notably in the upper Grana and Maira Valleys,

[1] "The Permian Formation in Piémont, Dauphiné, and Savoy": Geol. Mag., January, 1916, p. 7 et seq.

[2] D. Zaccagna, "Alpi Marittime": Boll. R. Com. geol., 1889, p. 395 et seq.

[3] S. Franchi, "Zona Pietre Verdi fra l'Ellero e la Bormida, Alpi Marittime": ibid., 1906, p. 89 et seq.

[4] The nomenclature used throughout this paper is that given in the preceding one, Geol. Mag., April, 1916, pp. 156–63.

similar euphoditic and diabasic masses occur in the calc-schist formation, but intensely metamorphosed, the former to epidotic and chloritic prasinites with or without gastaldite (blue secondary hornblende), the latter to felspathic prasinites and amphibolites.[1] These pietre verdi masses bear close analogy to the euphoditic and diabasic, also variolitic masses with overlying serpentine in the calc-schists of Maurin and of the Chabrière Valley, near Pointe de Mary, about 30 kilometres further north-west, as also to those of the Mont Genèvre group another 30 kilometres further north, and to those between the Ripa and Troncéa Valleys about 20 kilometres east of Genèvre. From the occurrence of all these crystalline masses both of eruptive[2] and sedimentary origin on the northern and eastern flank of the Permian horizon, Franchi has rightly concluded that that formation separates the Trias into two distinct zones: an external one on the left, composed of the ordinary, fossiliferous limestone, gypsum, and cargneules or Briançonnais facies, and an internal zone, the crystalline and semi-crystalline facies composed of the calc-schists and crystalline and dolomitic limestone with pietre verdi.[2]

2. *The Argentera Massif* (Fig. 1).—This massif, also called Mercantour, is an oval-shaped ellipsoidal group of 60 by 25 kilometres in approximate length and width, extending west of Col di Tenda along the French frontier, and bordered on the north by the Stura di Cuneo Valley, which separates the Maritime from the Cottian Alps. The massif includes, besides Monte Argentera (3,397 m.) and Monte Matto (3,057 m.) in the centre, some of the highest mountains of the Maritime Alps, e.g. Mercantour (2,775 m.) and Monte Clapier (3,046 m.) at the south-eastern, and Monte Tinibras (3,032 m.) at the north-western end. The access to the central part is by the Gesso Valley from Valdieri, whose well-known hot sulphur springs rise in the upper valley, at 1,346 metres altitude, almost in the centre of the massif. The latter is, like the Dora-Maira and Gran Paradiso gneiss massifs, entirely free from pietre verdi on its surface; even the fringe of pietre verdi which surrounds those massifs is absent on its periphery. Zaccagna attributes this isolation of the Argentera massif to a great fault along the Stura Valley, which latter is, some 20 kilometres north-east of Valdieri, crossed by a succession of pietre verdi outcrops descending from the Maira and Grana Valleys towards Cuneo and S. Dalmazzo, and thence running along the base of the Montgioie range to Villanova and Millesimo.

The Argentera massif consists, in the main, of three crystalline formations: a nucleus of primitive, glandular, large-grained, granitoid,

[1] S. Franchi, "Alcuni Metamorfisi di eufotidi e diabasi Alpi Occid.": Boll. R. Com. geol., 1895, p. 181 et seq. The transformation described in this important memoir applies equally to similar phenomena in all the other pietre verdi areas of the Piémontese Alps. In the massive and schistose amphibolites of the Grana and Maira Valleys, as also in Val Chisone, at Pegli, Liguria, and in the Tuscan archipelago, Franchi found the equivalent of the Californian mineral lawsonite, a secondary pseudomorphic plagioclase corresponding to the formula of hydro-anorthite felspar (Boll. R. Com. geol., 1898, p. 308).

[2] The term 'eruptive' is used in this paper in preference to 'igneous' as better corresponding to the non-intrusive character of the Piémontese rocks.

and eye-gneiss;[1] a large area, about 12 by 10 kilometres, of granite intrusive in the gneiss nucleus; and a surrounding belt of great masses of small-grained gneiss and mica-schist. The primitive gneiss, and to a much lesser extent also the intrusive granite is traversed in all directions by countless thin veins of acid rocks, chiefly microgranite, aplite, quartziferous and hornblendic porphyrite, while the outer gneiss contains intercalated masses of both augitic and hornblendic diorite and of compact serpentine. These rocks, being here intimately associated with gneiss, are not pietre verdi with secondary elements; but they show that the prototypes of the latter are not wanting even in the more ancient crystalline series.

Professor Sacco regards the position of the gneiss and granite of the Argentera massif as reversed, viz. the granite not as intrusive, but as constituting the nucleus of the massif, enveloped by an enormous mass of gneiss intensely metamorphosed and of Permo-Carboniferous age[2]; but Franchi's interpretation[3] is no doubt correct, the more so as there is no passage from gneiss to granite, and the intrusive character of the latter is beyond question. Moreover, the Triassic beds on the eastern as well as the Permian on the southern periphery of the massif overlie the gneiss with marked unconformity, thus pointing to a long interval of deposition and therefore to a considerable difference of age between the gneiss and the overlying younger formations.

II. The Monte Viso Group. (Figs. 1 and 2.[4])

This area forms an elongated lenticular ellipsoid from south to north, about 40 kilometres in length and 2 to 6 kilometres in width, between the Maira Valley at its southern and the Pellice Valley at its northern end, while nearer the centre on its southern side it is cut by the Varaita Valley. In the centre itself, on the eastern side, rises the Po, which, although in its lower course it collects the drainage of all the rivers of the Piémontese Alps, is, in its upper torrential and cascade course, the shortest of all.

[1] The term 'primitive' gneiss is used throughout this paper in its strictly stratigraphical sense as the 'fundamental' substratum of all the more recent formations.

[2] F. Sacco, "L'Age du massif de l'Argentère": Bull. Soc. géol. France, 1907, vi, p. 484 et seq. Also "Gruppo dell' Argentera": Mem. R. Acc. Scienze, Torino, 1911, lxi, p. 457 et seq.

[3] S. Franchi, "Osservazioni lavori geol. Alpi Marittime": Boll. R. Com. geol., 1907, p. 145 et seq. Among the excellent reports in the Boll. R. Com. geol., besides those already quoted in this and the preceding paper, are the following relating to the Cottian Alps:—

S. Franchi, "Tettonica della zona pietre verdi del Piemonte," 1906, p. 118 et seq.; "Appunti geol. e petrogr. Monti di Bussoleno," 1895, p. 3 et seq.

S. Franchi and V. Novarese, "Appunti geol. e petrogr. dintorni di Pinerolo," 1895, p. 385 et seq.

V. Novarese, "Rilevamento geol. Valle Germanasca," 1895, p. 253 et seq.; "Rilevamento geol. Valle Pellice," 1896, p. 231 et seq.

A. Stella, "Rilevamento geol. Valle Varaita," 1895, p. 283 et seq.; "Rilevamento geol. Valle Po," 1896, p. 268 et seq.

[4] Figs. 2–4 will appear in the next part of this paper in June.

The majestic appearance of Monte Viso—Pliny's *Mons Vesulus*—is largely owing to the surrounding area of calc-schists having been considerably lowered by erosion which scooped out a socket-like depression round the base of the more resistant pietre verdi mass, and thus made the pyramid—the highest point of the Cottian Alps—all the more imposing. Close to it rise two similarly shaped but lower spurs: Visomut on its eastern side, and Visolotto grafted on its western flank, all three being in their upper or pyramidal parts composed entirely of pietre verdi. The same applies to Colle delle Traversette (3,287 m.) at the western, to Monte Granero (3,170 m.) at the northern, and to Lobbie di Viso (2,990 m.) at the southern end of the group, which thus forms an enormous lenticular mass in the calc-schist formation, parallel to the Dora-Maira gneiss massif which separates it from the Po plain.

1. *The Pietre Verdi Area of Monte Viso.*—The least difficult access to the central part of the group for examining the pietre verdi series is from Barge (500 m.) to Paesana and thence up the Po ravine to Crissolo (1,335 m.) and to the summit of Monte Viso (3,843 m.), the four stages being (1) the eastern mica-schist zone to Paesana; (2) the Dora-Maira gneiss massif, in the ravine or *chiusa* of which the Po is joined by the torrent Lenta; (3) the western mica-schist, and then the predominant calc-schist formation with the quarried crystalline limestone beds of Crissolo; and (4) the pietre verdi up to the summit.

The base of the Visomut spur discloses a great bank of serpentine passing to schist, at least 500 metres in thickness, followed to the top by alternating banks of gneissiform euphodite and euphoditic and amphibolic schist, the former conspicuous by smaragdite, the latter by its epidotic veins, both of which minerals are largely prominent throughout the whole Monte Viso group. The depression between Visomut and Monte Viso, in which are embedded Lago Grande and other tarns, is composed of calc-schist, chloritic and serpentinous schist. From this point the succession of pietre verdi banks can be traced uninterruptedly to the summit of Monte Viso along the path leading from the Quintino Sella refuge (about 3,000 m.) up the southern flank. From the refuge, which is built on a felspathic euphodite bank, to the summit, the flank presents a series of alternating banks—as shown in the section, Fig. 2 [1]—of euphodite, epidotic, amphibolic, actinolitic, and prasinitic schists from 200 to 300 metres in thickness, with smaller intervening banks of serpentinous schist. The euphodite, varying from compact to schistose, is largely of porphyric texture with greyish violet felspar and diallage altered to smaragdite. The amphibolic and prasinitic schists and their varieties predominate largely, and, together with euphodite, constitute the summit of Monte Viso, as they also do that of the almost perpendicular

[1] This section is founded on Zaccagna's great transverse section west to east of 70 kilom. from St. Paul in Dauphiné through the calc-schist formation, Monte Viso, and the Dora-Maira massif to Rocca Cavour in the Po Valley (Boll. R. Com. geol., 1887, p. 416, tav. ix). Franchi gives a similar section of the Monte Viso group at a lower level further south (ibid., 1898, p. 482, tav. ix; also Stella, ibid., 1896, p. 288). (For Fig. 2 see June Number.)

peak of Visolotto. In all the alternating banks the gradual passage into, and compenetration with each other is very marked, and so is more especially the tendency to chloritic decomposition forming serpentinous schist, which in contact with narrow bands of crystalline limestone imparts to the latter its greenish colour.

The descent from Monte Viso may, on the southern side, be conveniently effected by the Forciolline gorge, and thence through the Vallante ravine and the Varaita Valley by Sampeyre and Venasca to Saluzzo in the Po Valley. In those deeply eroded ravines the calc-schist formation reappears in contact with amphibolic, prasinitic, and serpentinous schist. At the junction of the Vallante and Varaita Valleys the last-named schist predominates, and lower down the latter valley is replaced by alternating banks of calc-schist, serpentine, and chloritic amphibolite.

2. *The Gneiss, Mica-schist, and Graphitic Area.*—Parallel to and east of the pietre verdi area of Monte Viso runs, as already mentioned, the Dora–Maira primitive gneiss massif, about 60 kilometres in length and 5 to 10 kilometres in width, at an altitude of 1,500 to 2,000 metres, the visible thickness being about 700 to 1,000 metres. Its superficial continuity is, however, frequently interrupted by great intervening, overlying, or intercalated masses of minute, granular, and tabular gneiss, with which are associated masses of crystalline limestone, quartzite, steatite, and dioritic, amphibolic, and prasinitic rocks. The primitive gneiss is the typical rock with large elements, glandular, often granitoid, and tourmaliniferous; the mica-schists, often garnetiferous, and the minute, tabular gneiss flank the primitive gneiss both on the eastern and western side. Of the gneissoid dioritic rocks associated with the minute and tabular gneiss, which latter reaches, e.g. in the Pellice Valley, a thickness of 1,500 metres, an intercalated mass 700 metres in thickness occurs near Barge; another, 1,000 metres, near Angrogna (Pellice); and again, in the Chisone Valley, another 1,500 metres in thickness, where the dioritic rock is associated with and altered to amphibolites and prasinites, including the ovardite of Fenestrelle. Both the tabular gneiss and the crystalline limestone, often associated with steatite, are extensively quarried on the eastern side of the Dora–Maira massif, at Vernasca, in the Varaita, near Luserna, in the Pellice, and near Malanaggio, etc., in the Chisone Valley, as are also the fissile, tegular, quartzite masses (*bargiolina*) of Monte Bracco (1,305 m.) near Barge.

In the same mica-schist and minute gneiss horizon occur masses of graphitic rock with intercalations of graphite, which, flanking Monte Bracco on its western side, extend about 20 kilometres south, and about the same distance north of Barge. It is here, in the Pellice and Chisone Valleys, that the graphitic zone is associated with the gneissoid dioritic rocks already mentioned. The whole mica-schist, minute gneiss, graphitic and dioritic zone is now assigned to the Permo-Carboniferous.

3. *Summary.*—The Monte Viso and Dora–Maira areas may be grouped, in ascending order from east to west, viz. from Barge in the Po Valley to Crissolo and the summit of Monte Viso, in a distance of 20 kilometres, in four horizons as follows:—

	Altitude. m.	Visible depth. m.
I. Primitive gneiss of Dora-Maira massif, glandular to granitoid II. Mica-schists, minute, tabular, and graphitic gneiss with quartzite, crystalline limestone, steatite, graphite, and dioritic rocks	500–2,000	1,500
III. Calc-schists with crystalline limestone, serpentine, and amphibolic schists	1,300–2,000	700
IV. Pietre verdi to summit of Monte Viso; serpentine and serpentinous schist; epidotic amphibolites; glaucophanic prasinites; actinolitic, chloritic, and talcose schists; euphodites, gneissiform, porphyritic, and schistose	2,000–3,800	1,800
		3,300

The total visible thickness between the extreme points—exclusive of the fall of level in the depression between the gneiss massif and the calc-schist horizon on the western flank of the former—is thus 3,300 metres.

The fact that the mica-schist horizon flanks the gneiss massif on both sides, but on the eastern side along the base, viz. at a lower level, led Gastaldi to regard this reversal of the normal sequence as evidence of a zonal subsidence (*sprofondamento*), the more so as both formations dip below the valley floor and reappear about 6 kilometres east in the isolated outcrop of Rocca Cavour (460 m.). Zaccagna, on the other hand, explained the phenomenon as an anticlinal retroflex fold of the gneiss massif from west to east. As a zonal fracture or subsidence, it bears close analogy to similar zonal phenomena in Northern Piémont, to which I shall refer in the sequel.

(*To be continued in our next Number.*)

IV.—On Tridymite and Quartz after Tridymite in Icelandic Rocks.

By Leonard Hawkes, B.Sc.

(PLATE IX.)

A. LACROIX in his researches on volcanic rocks and their inclusions has shown that tridymite occurs in two distinct forms, each produced under special conditions. "Il est important de constater dans un même échantillon l'existence de tridymite produite par deux modes de genèse distincts; qui lui ont imprimé deux formes différentes. L'une d'elles est caracterisée par des cristaux épais, à macles binaires, elle a été formée par fusion; l'autre se présentant en lamelles extrêmement minces, empilées a été produite par action pneumatolytique. Cette variété de tridymite constitue le dernier des minéraux drusiques formés, et elle résulte très probablement de l'attaque à haute température d'un résidue de matière vitreuse très siliceuse dont des restes peuvent être parfois encore constatés directement" (**1**, p. 337). Both forms occur in Icelandic rocks.

In his description of the liparite of Hlidarfjall, Bäckström notes "sehr schönen Tridymite als letzte Bildung" (**2**, p. 661). Through the kindness of Professor Bäckström I was enabled to examine his

rock sections, and a microphotograph showing the characteristic form of the tridymite is given in Fig. 1. The crystals are thick and frequently show binary twinning after (013). Their resemblance to the artificial tridymite from the bricks lining the glass furnaces of Appert, Clichy, in France is obvious (cf. Fig. 2, **1**, p. 331). The commoner form of tridymite, that of thin tables, is well shown in a breccia from Faskrudsfjord, East Iceland, consisting chiefly of fragments of an acid rock embedded in acid volcanic ash. This rock, 80 feet in thickness and intercalated in the Tertiary basalts, is exposed on the shore about a mile east of the town. The fragments of ash and lava contain phenocrysts of soda-microcline and soda-pyroxene in (*a*) a glassy perlitic base and (*b*) an aggregate of felspar quartz and pyroxene grains, respectively. In (*a*) the perlitic groundmass is often weakly anisotropic, being made up of thin plates of tridymite. In (*b*) similar tridymite occurs together with quartz (described below) in cavities, and apparently in the groundmass. The nature and mode of occurrence of the two forms of tridymite of Hlidarfjall and Faskrudsfjord are in full accord with the theory of their mode of origin advanced by Lacroix.

Quartz after Tridymite.

The quartz to be described occurs in the rock of Faskrudsfjord. The pseudomorphs are of two types, both originating from the thin tabular form of tridymite.

Type I.—Previously noted by Mallard (**3**, p. 162), Lacroix, and Geijer (**4**). The holocrystalline fragments of the Faskrudsfjord breccia contain cavities filled with quartz, chlorite, and a small amount of a feebly double refracting mineral of low refraction, probably tridymite. A microphotograph of a cavity is given in Fig. 2. The quartz is of peculiar habit, forming a complex of lamellæ branching out from one another at different angles. The network of laths in the cavity illustrated in Fig. 2 is comprised of two individuals, distinguished optically. While several lamellæ may form one individual of common optical orientation, the laths forking without change in optical properties, one straight lath may be composed of many individuals. Fig. 3 shows another assemblage of laths comprising five individuals. This quartz is undoubtedly a paramorph of tridymite, and Geijer has described a similar occurrence in cavities in a pre-Cambrian quartz porphyry found as boulders in a moraine on Gotland. (See especially the photograph on p. 71, **4**.) The quartz of the holocrystalline groundmass of the Icelandic rock is micropoikilitically developed, and without going into the question of micropoikilitic reticulating quartz which has been discussed by Geijer, it may be stated that it too, judging from its occurrence and association, is very probably a pseudomorph of tridymite. It is interesting to note that the soda-microcline phenocrysts, which typically show inclusions of glass, sometimes contain lamellar quartz after tridymite (see Fig. 4), thus indirectly supporting Lacroix's theory of the formation of tabular tridymite, "de l'attaque à haute temperature d'un résidue de matière vitreuse très siliceuse."

Type II.—The paramorphs of Type I are characterized by the

retention of the lamellar form of the tridymite. In those now to be described the outline of the quartz is not that of the tridymite lamellæ, being more or less rounded. This type is well illustrated in a fragment 1 mm. in diameter, composed of twenty-three variously sized quartz grains, embedded in the Faskrudsfjord rock. Fig. 5 is a microphotograph of a part of the fragment, and Fig. 6 shows its outline and that of its component individuals. The quartzes are allotriomorphic with respect to one another, and a rapid glance conveys the impression of the usual granitic texture. On closer investigation, however, they are seen to have straight lines running

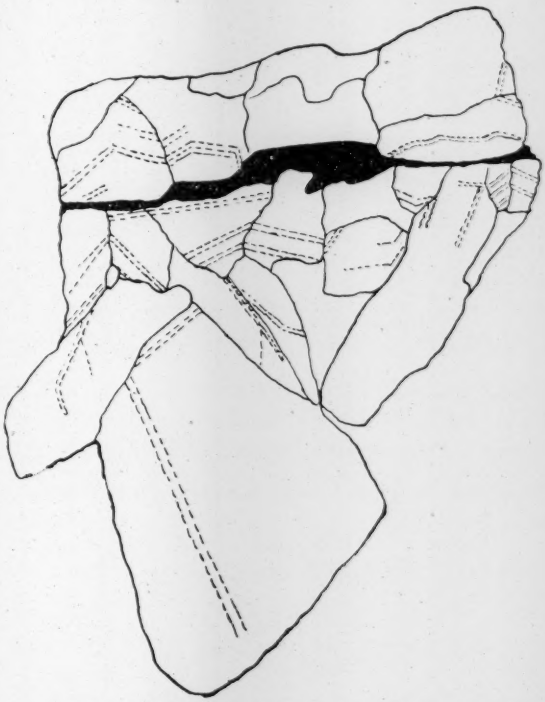


FIG. 6.—A drawing of the aggregate of Fig. 5. The dotted lines are the traces of the former tridymite lamellæ.

through them, commonly in pairs, giving a rod-like appearance. Some of these lines are very distinct with a medium magnification, and they can be seen in Fig. 5, but many of them are only discernible using a high power and after continued observation. The lines discovered are dotted in in Fig. 6 ; none could be found in some of the quartzes. The structure is seen on slight movement of the microscope tube. The lines are dark and accompanied by ' white lines ', those forming a ' pair ' or ' rod ' deflecting in the same horizontal direction on movement of the tube. The lines obviously represent planes or cracks, each pair having a common inclination to the plane of section.

Sometimes several parallel lines have a common inclination clearly representing a section cut across several parallel imbricated lamellæ. The lamellæ join at varying angles, their junction often coinciding with that of the quartz individuals; though two joined lamellæ may be contained in one individual. In one case three parallel lamellæ of one quartz are joined at an angle to three parallel lamellæ of an adjoining quartz, at the line of junction of the two individuals. Again, one straight lath may be contained in two quartzes. The lamellæ commonly have a line of dark dust inclusions along their middle or surface. In general there is a tendency to coincidence in direction of the lamellæ and the length direction of the quartz individuals. Fig. 7 is a drawing illustrating another homogeneous quartz filling a cavity and showing traces of a former complex of tridymite tables.

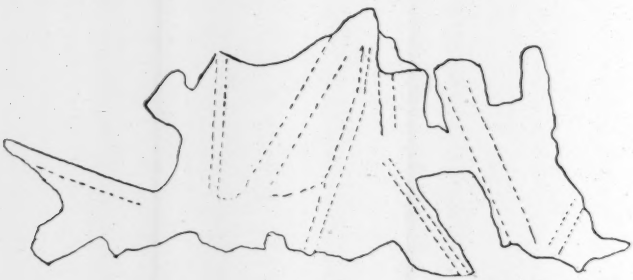


Fig. 7.—Drawing of a single quartz individual, showing traces of an original complex of tridymite lamellæ. × 150.

It is clear that this granular quartz of Type II is merely a further evolution of that of Type I. Taking the lamellæ in the granular quartz by themselves, their morphological and optical characters exactly correspond to those of the tabular quartz of Type I. In a complex of tridymite lamellæ the paramorphism to quartz begins in certain of them, many going to form a single individual or one being changed into several, producing the structure of Type I. A further step is the paramorphism of the tridymite occupying the interspaces between these laths, and, probably through inoculation, the quartz formed is in optical continuity with that already present, giving rise to homogeneous granular individuals. The quartz shown to the left in Fig. 2 is obviously in the transition stage between the two types. The laths are the scaffolding on which the granular individual is moulded.

The question arises as to whether we have been correct in regarding all granular quartz in igneous rocks as primary. The evidence is quite conclusive that the quartz individuals of Type II in the Faskrudsfjord breccia are paramorphic after tridymite, yet in some of them the tridymite structure is only discernible with considerable difficulty, and in a few it is entirely eradicated. The importance of this fact in questions concerning the temperature of crystallization of quartz is obvious, and whilst it is unlikely that much granular quartz has originated from tridymite in the way

FIG. 1. FIG. 3.

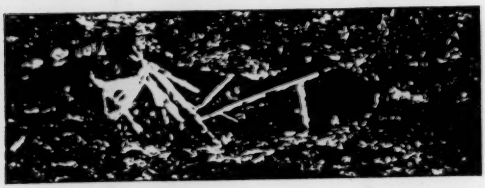


FIG. 2

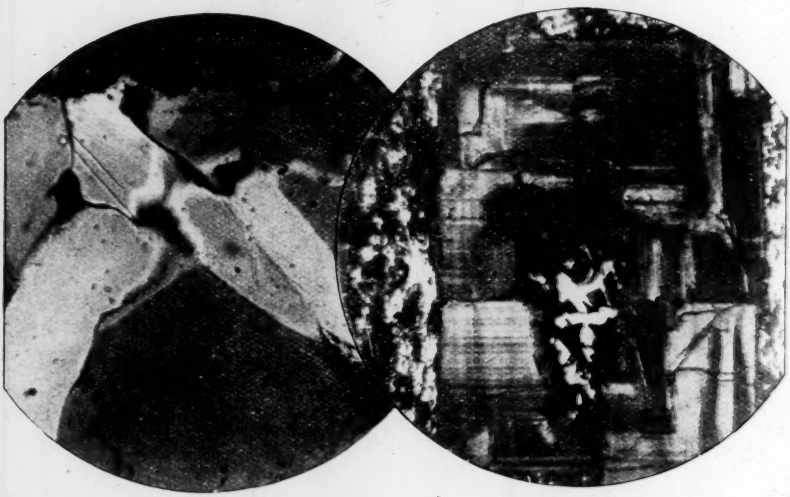


FIG. 5. FIG. 4.

TRIDYMITE AND QUARTZ IN ICELANDIC ACID ROCKS.

described, it is desired to draw the attention of petrographers to the structure, in the hope of finding it to be of wider occurrence.

In quartz-porphyries with micro-poikilitic structure the quartz phenocrysts are often surrounded by a network of quartz laths in optical continuity. Geijer regards the laths as paramorphic after tridymite, and suggests that their optical continuity with the phenocrysts may be due to inoculation by the latter. The discovery of the granular quartz suggested the possibility of these phenocrysts themselves being paramorphs of tridymite, and through the kindness of Professor P. D. Quensel, of Stockholm, I was permitted to look through Dr. Hedström's slides described by Geijer. There were no traces in the phenocrysts of any structure similar to that in the Faskrudsfjord rock. Unfortunately there are no quartz phenocrysts in the Icelandic rock, and it is impossible to speak definitely yet on the question of phenocrysts and micropoikilitic quartz.

I wish to express my thanks to Professor W. C. Brögger for permission to work at the Mineralogical Institute of the University of Christiania, and to Professor V. M. Goldschmidt for help and advice.

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EXPLANATION OF PLATE IX.

FIG. 1.—Nicols crossed. Section of the Hlidarfjall Liparite (Professor Bäckström's collection), showing an assemblage of thick twinned tridymite crystals. × 40.

,, 2.—Nicols crossed. Section of a fragment in the Faskrudsfjord rock, showing typical development of quartz lamellæ—paramorphs of tridymite—in a cavity. The lamellæ comprise two quartz individuals. The light streaky patches in the groundmass are micropoikilitic quartz. × 40.

,, 3.—Nicols crossed. Section showing a complex of quartz lamellæ—paramorphs of tridymite—in a cavity in a fragment of the Faskrudsfjord rock, and optically resolvable into five individuals. × 120.

,, 4. Nicols crossed. From the Faskrudsfjord rock, showing a phenocryst of soda-microcline with albite and pericline twinning, and holding as an inclusion quartz lamellæ, paramorphs of tridymite. × 120.

,, 5. Nicols crossed. From the Faskrudsfjord rock. Shows an aggregate of quartz grains with traces of tridymite lamellar forms. × 120.

V.—FURTHER GEOLOGICAL NOTES ON THE LAND OF DEEP CORROSIONS.[1]

By F. KINGDON WARD, B.A., F.R.G.S.

IN the GEOLOGICAL MAGAZINE for April, 1913,[2] I drew attention to certain features of the country forming the Yunnan–Tibet border. Further travels there in 1913 and through the Burmese hinterland in 1914 enable me now to supplement and extend those notes.

[1] The rock specimens collected during my journeys of 1913 and 1914 have not been described. Their examination may help to throw some light on the problems here indicated.

[2] "Geological Notes on the Land of Deep Corrosions," pp. 148–53, Pls. V and VI.

Many travellers crossing Western China between Burma and Ssuchuan have regarded the endless parallel ranges which have to be crossed as spurs thrown out from the main Himalayan range or from the Tibetan plateau, at least as far south as Likiang. Thus Captain Gill writes: "The great plateau that extends over the whole of Central Asia throws down a huge arm between the Chin-sha-chiang (Yangtze) and the Lan-tsang-chiang (Mekong), gradually diminishing in altitude as it extends south. The northern portion of this arm partakes more or less of the character of the main tableland . . . this arm is not more than 35 miles wide in the latitude of Batang and . . . it is little more than a ridge of mountains running due north and south between the two streams" (*The River of Golden Sand*, vol. ii). West of Batang the summit of this divide is, as Captain Gill indicates, an undulating grass-land plateau cut up by streams flowing in shallow valleys, with lakes occupying hollows here and there, from 12,000 to 14,000 feet above sea-level; in appearance it closely resembles the grass-land country of North-East Tibet, on the Kansu border. But from Atuntsi southwards to Likiang the divide narrows down to a mere rock wall.

However, it is inconceivable that the Mekong–Yangtze divide was formed independently of the Mekong–Salween and Salween–Irrawaddy divides, which so closely resemble it in structure, as well as in their flora; if the Mekong–Yangtze divide is an arm of the great plateau, or a spur of the Himalayas, so too are its immediate neighbours, the Mekong–Salween and Salween–Irrawaddy divides.

The same characteristics are repeated throughout the country to the east of Batang, though in a less sensational manner. The whole of the immense mountainous region lying between Batang and Tatsienlu and between the parallels of 32° and 26° partakes of the same nature, and though I do not know it at first hand the accounts of the few travellers who have been there emphasize the fact that it is a region of high parallel mountain ranges, often snow-clad, trending north and south, with rivers flowing south in deep narrow valleys between. However, in all this country there is no river to compare with those of the Yunnan–Tibet border, the Yalung being the only one of any size, though even beyond Tatsienlu the Ta-tu, and beyond that again the Min, also flow south.

Captain Gill says of the country between Tatsienlu and Batang the day after leaving the former city: "A few yards more, and reaching the summit of the Cheh-toh-shan we at length looked upon the great Himalayan plateau . . . and from this point, with the exception of a dip into the Yalung-chiang, the road is always at an altitude of 12,000 feet above the sea until the descent into the valley of the Chin-sha-chiang . . . " (*The River of Golden Sand*, vol. ii).

The object of the present paper is to insist on the relationship and common origin of the physical features of the entire region from the Brahmapootra in Assam, across the sources of the Irrawaddy in the Burmese hinterland and the Yunnan–Tibet border, into Western China. There is no reason whatever to believe that this region may be regarded as a dissected plateau—that it was uplifted in its entirety at the same time as the Tibetan plateau and subsequently dissected

by rivers all flowing in one direction, leaving parallel mountain chains between. Why do the rivers all flow in one direction? Moreover, there is a significant curiosity about the courses of some of these rivers. The main lines of drainage run due south, parallel to the great ranges, since they cannot as a rule flow across them (hence the ranges antedate the rivers, or are perhaps contemporaneous with them). But why should the tributary streams throughout their greater lengths flow strictly parallel to the main rivers, finally turning abruptly at right angles to join them? This is true of the tributaries of the Mekong and Salween, and is even more pronounced in the case of the 'Nmai-hka. The explanation, I think, lies in the fact that the region is traversed by parallel lines of weakness, produced in a manner to be described presently, and it will probably be found that the tributaries turn at right angles to join the main rivers where a change in the character of the rocks occurs.

Of the parallel rivers, the Mekong is the most easterly that continues its southern course to the sea. The Yangtze, after a series of remarkable loops, turns away to the east, thus snapping up all the rivers beyond which flow southward, and it has been suggested that it too, like the Mekong and Salween, once had an outlet to the south, through Indo-China. On what evidence that supposition is based I do not know, but a valley or series of valleys running southwards from Likiang, where the Yangtze abruptly ceases to flow southwards, to Tali-fu, now occupied by a chain of lakes and marshes draining south to the Mekong, of which the Tali-fu Lake itself is by far the most conspicuous, lends colour to the suggestion; there are also hot springs all the way along this shallow depression, and records of numerous earthquakes, leading to the belief that considerable crust movement has taken place here. The rocks are mainly sandstones, shales, and limestone—crystalline on the Tali-fu range.

The big N-shaped bend of the Yangtze, at the end of its southern journey, just before it definitely sets out eastwards towards the Japan Sea, in the course of which it cuts diagonally across the Likiang range, *not* flowing round it as is shown on the maps, is peculiar, but by no means unique in this region. Here I need only remark that the fact of the river cutting across the range suggests that this portion of that river at least existed prior to the uplift of the lofty Likiang range; but it was not then necessarily the source stream of the Yangtze as we now understand that river. It is much more likely that the Chin-sha-chiang (reserving this name for the southward-flowing upper portion of the Yangtze) did actually continue southwards past Likiang, being subsequently beheaded by the upper course of the eastward-flowing portion cutting back westwards; the southern portion of the Chin-sha-chiang, being thus isolated from its source, ultimately disappearing. This would account for the abrupt change of direction of the Yangtze, but not altogether for the extraordinary double loop into which it bends itself, unless we suppose that the western loop was originally a tributary of the independent Chin-sha, the water of the latter being eventually diverted through the channel of the former to join the Yangtze. At any rate this peculiarity is shared by at least three other rivers of

this region, namely, the Yalung, the Dayul River (or Wi-ch'u), and the Ngawchang-hka, while the upper portion of the 'Nmai-hka attempts a similar evolution and achieves a double bend, each half of which is less than a right angle. By the pinching of the rivers between rocks subjected to two sets of earth movements acting at right angles to each other, in some cases actually buckling the strata, and to cutting back, owing partly to differences of rainfall on the two sides of a mountain range and partly to differences of level and of grade in the river-beds, which has gradually brought rivers originally belonging to separate hydrographic systems into contact, I imagine the whimsical courses of these rivers to have been evolved from simple courses. Whether this explanation be right or wrong, there can be no doubt that the several rivers which exhibit this phenomenon of reversed flow owe it to a common cause, and not to some chance freak in each case.

It may be asked, what became of all the rain-water which must have fallen on this country previous to the west to east movement which, by cutting across and breaching the long axis of the great Asiatic divide, allowed the parallel rivers to drain southwards? The answer is, much of the region was then occupied by vast lakes into which the water was poured. In the case of Hkamti–Loong, to be referred to presently, at the sources of the Mali-hka (or western branch of the Irrawaddy), it is sufficiently obvious that this plain was once occupied by a lake, and again much further east we have an ancient lake bottom in the 'red basin' of Ssuchuan, now the fertile Chengtu plain. But there is proof in the sandstones, slates, and limestone of the border country itself that most of it was once under water. Much of the Mekong–Yangtze divide, for instance, is capped by limestone now raised 18,000 or 20,000 feet above sea-level, and the same rock reappears on the ranges to the west. North of Likiang we cross plateau country partially occupied by insignificant lakes, surrounded by sandstone or limestone ranges from the bases of which well up hot springs. But whereas the Hkamti plain is only 1,200 feet above sea-level, with parallel ridges of sands and clays enclosing organic remains still intact, rising 3,000 or 4,000 feet higher in the south, the old sea or lake bottoms east of the Yangtze have been pushed up into plateaux 8,000 to 12,000 feet above sea-level, and regional metamorphism must have obliterated any organic remains which may once have existed. Whereas the isolated lakes of Tibet are drying up, those of the Yunnan–Tibet border country have been drained.

As already remarked, this border country has, in my opinion, been subjected to two sets of crust movement acting approximately at right angles to each other in such a manner that the hydrographic system set up during the first phase, at a later period became involved with and largely obliterated by that resulting from the second phase; further complications were gradually introduced by the cutting back of either the primary or the secondary rivers, but especially by the former, according to local circumstances. During the first phase the Himalayas and the main backbone of China, separating the Yangtze and Yellow River basins, were raised up; during the second,

the north and south trending parallel ranges which lie between Assam and Western China, though the Himalayas may have and probably did receive their last and greatest uplift (in Tertiary times) at a subsequent date.

During the period of the first phase the region we are considering may have appeared somewhat as follows: (1) The Himalayas, either continuous with, or at least throwing out spurs to, the main divide of China (a consideration of the distribution of plants on the Himalayas and in Western China leads to this conclusion). (2) A great lake or system of lakes stretching throughout the present headwaters of the Mali-hka westwards into Assam, and covering thousands of square miles. (3) A region of great lakes and volcanic activity in Western China. (4) A number of rivers flowing into these rivers from the west, of which the upper courses of the Brahmapootra and Salween may have existed more or less as at present, eventually becoming involved with rivers consequent upon the second phase.

At this time the Irrawaddy can have had no existence, nor probably had the Mekong. The Yangtze, however, flowed eastwards from the neighbourhood of the Chengtu plain, then a vast lake; its present upper course (distinguished as the Chin-sha-chiang) did not exist, and the same applies to the lower course of the Salween.

The second great phase now seems to have been initiated by a crust movement from west to east, accompanied by the irruption of vast masses of granite. It may be that a lateral shifting of the Himalayan axis eastwards accounted for this, or perhaps it was due to a natural shrinking and settling of the crust; but whatever the cause, the parallel ranges to the east were those first formed, the western ones being pushed up later (the glacial phenomena and the distribution of flora on the parallel divides show this).

The result of this second earth movement was to break the continuity of the Sino-Himalayan axis, and start rivers flowing southwards through the breach. Thus arose the Mekong and the lower course of the Salween from about latitude 29°, while the draining of the Hkamti–Assam country gave rise to the Irrawaddy. At this time too the Chin-sha may have flowed southwards past Talifu to the sea through Indo-China. The parallel divides were then much lower than at present, and the monsoon rains swept on into Western China, where there were great glaciers. Meanwhile the rivers of the old system were rapidly cutting back, with the result that the Yangtze eventually tapped the Chin-sha, while the lower and upper courses of the Brahmapootra, cutting down as the Himalayas rose, became united. All this time the parallel divides were being slowly elevated, gradually pushed up one by one from the west, but the probability is that they had attained no great elevation till the present hydrographic system was established, and there is reason to believe, from a consideration of the glacial phenomena on the Mekong–Yangtze and Mekong–Salween divides—a matter which requires separate treatment—that they are still rising.

I have stated my belief that the parallel divides, with their intervening valleys, were formed by pressure from the west—that is to say, that the region is a series of anticlines and synclines; and on

the whole it appears to be so. But the gorges in which flow the 'Nmai-hka, Salween, Mekong, and Chin-sha are not simple synclines deepened by erosion; they are more in the nature of rifts, gashes, or possibly faults produced by some other agency.

If we cross all the valleys and mountain ranges, starting from the Brahmapootra, and travelling eastwards, keeping always in the same latitude, we shall find that as we pass from one valley to the next, we are gradually ascending, and also crossing successively higher mountain ranges between them, till the maximum average height is reached on the divide separating the Mekong from the Chin-sha for the short distance these rivers flow parallel to one another. The Mekong–Yangtze divide, however, is not the most snow-clad, for being protected from the monsoon by rain-screens to the west it receives only a fraction of the precipitation which falls on the western ranges, exposed to the full onslaught of the monsoon. Thus the entire region from the Brahmapootra to the Yangtze, in about latitude 28°, presents the appearance of a hugh bulk of rock, crystalline in the east, inclined from west to east, and trenched, riven, split asunder again and again from north to south.

Now how are we to account for the fact that the river beds from west to east, irrespective of volume and velocity and therefore of their erosive powers, namely, in order the Brahmapootra, Mali-hka, 'Nmai-hka (western and eastern branches of the Irrawaddy respectively, the latter being the *main* stream), Salween, Mekong, and Chin-sha (Yangtze), lie at successively higher and higher levels? The problem is complicated by the fact that the rivers are of different ages, the Irrawaddy evidently being the most recent, while the Chin-sha is probably the oldest. The regularity of the ascent is not due to a progressive decrease in the erosive power of the rivers, due either to a decrease in grade, to a decreased volume of water, or to any difference in the composition of the rocks over which they flow. The Mekong is a bigger and swifter river than the 'Nmai-hka, but it flows at a higher level by some 2,000 feet. The Salween has a bigger volume of water than the Mekong, but flows over 1,000 feet below it. We cannot ascribe the phenomenon to chance, and the only explanation seems to be that the country really does represent an inclined block of strata; and unless it has itself been planed down and carved out in this way, which is what we are endeavouring to show that it has not, and that it never existed above water *except* as a series of parallel ridges and valleys, we are almost forced to the conclusion that it must have been pushed bodily up over an inclined plane of older rock which it now overlaps. This sorts well with the belief, founded on a consideration of glacial phenomena and floral distribution, that the ridges were pushed up one by one from the west, by a lateral movement of the Himalayan axis. If such bodily movement of the mass did take place, it is easy to account for the rifts in which the rivers now flow, by fracture. If the pressure which gave rise to the original underlying synclinal structure was sufficient also to force this huge mass bodily up an inclined plane of older strata, sloping gently down to the west, at less than a degree,[1]

[1] If the slope from the Chin-sha Valley to the Brahmapootra were uniform, it would be, in round numbers, about 1 in 3,000, or a slope of 20 *seconds*.

then any cessation or diminution of that pressure might allow the overlaying strata to sag back. The result would be that on the steeper slopes—for the slope from west to east is manifestly not uniform—the massive anticlines, dragging on the synclines, would cause the latter to crack, and rifts such as the parallel rivers now occupy would take the place of simple anticlines, accounting at the same time for the differences of level at which the rivers flow. The rifts once formed would be deepened by erosion, the valley walls being protected by the aridity enjoyed, which is itself increased automatically by the up-valley winds. It is, however, evident that these aggravating factors alone are not sufficient to account for the rifts in the first instance, since the Salween, south of latitude 28° in a monsoon region, flows through a very narrow valley, the rocks in the bed of which in all respects resemble those further north, and in places through gorges modified by the heavy summer rainfall; still more does the upper 'Nmai-hka (or Taron as it is now called) flow in a gorge, though the region is drenched with rain almost all the year round.

Or, we may account for the rifts, and perhaps also for the marked differences of level, not by any lateral movement of the Himalayan axis, but by the elevation of that range itself, setting up a great tension strain at right angles in the adjacent crust, causing a sequence of parallel rifts to appear during the second phase referred to above, followed by an irruption of molten rock along the lines of weakness. Lines of volcanic activity can be followed southwards from Batang through Yunnan (T'engyueh volcano), Burma (Popa), the Arrakan Hills, and the Andamans (Barren Island), to the Indies, where the volcanic forces are at present concentrated, having forged southwards like a line of fire. In the case of a tension strain like that, the region most affected would be that nearest the seat of force, that is in the west nearest the Himalayas, where the broadest and deepest valleys would be formed; the least affected would be those furthest away, in the east, which would consequently be narrowest and highest. But while the rift formation may be due to this cause, and not to any pushing of the crust up a gently inclined plane with subsequent sagging back, it does not affect the synclinal origin of the great breach in the Sino-Himalayan axis, and the successive elevation of the parallel divides, the most easterly being those first elevated. This I now regard as proved from botanical and geological evidence.

It will be noticed that there is a tendency for the river valleys not only to lie at higher elevations, but also to become narrower, so far as is consistent with their different powers of erosion, as we go eastwards. Thus the Brahmapootra valley, once the Himalayan axis is cut across, is broader and flatter than that of the Mali, and the Mali than that of the 'Nmai-hka. There is probably little to choose between the gorges of the upper 'Nmai-hka (Taron), the Salween, and the Mekong, as regards breadth, but the Yangtze valley is rather broader, the river itself being quite twice as broad as the Mekong. If no disturbing factors intervene the western rivers will eventually tap the eastern, owing to the cutting back of the tributaries

on the rainy sides of the several divides and the gradual shifting of the watersheds eastwards. This is inevitable. Thus the 'Nmai-hka will tap the Salween, and the Salween the Mekong, south of latitude 28° (the southern limit of the arid region on the former river). The Mali might tap the 'Nmai—the watershed hangs right over the latter river at present, and the former will then become the main stream of the Irrawaddy, the 'Nmai disappearing; but an elevation of the Salween–Irrawaddy divide, by further concentrating the monsoon wind currents within the Irrawaddy basin, might prevent this by levelling up the present unequal distribution between the Mali and the 'Nmai; but it would also curtail tapping operations further east, south of the arid region, just as they have been stopped in the arid region itself, where the rivers grind out their gorges in isolated grandeur, indifferent to the freaks of their neighbours because independent of water save from the distant glaciers of Tibet.

It may be that the Mali has already tapped tributaries once flowing to the 'Nmai, and that it is gradually stealing all its waters on that side; certain it is that no rivers flow to the 'Nmai-hka from the west, and whereas we reached the crest of the Mali-'Nmai divide the second day after leaving the latter river, an endless series of ridges and valleys had to be crossed, occupying nine days, before the Mali was reached.

We come now to a brief description of the rocks in the valleys from the Yangtze to the Mali-hka, and on the intervening ranges in about latitude 28°. In the Yangtze valley slates and schists were noticed above, on the left bank, limestone below, but crossing to the right bank and ascending the Mekong–Yangtze divide the order was reversed—first schists, then limestone, after which came an outcrop of granite; altitude 9,000–10,000 feet. All these rocks were highly tilted, sometimes almost vertical, the schists crumpled; dip varying, but approximating to N.E. The summit of the divide is capped by limestone and a red grit, probably arkose; the former sometimes cropping out in irregular cavernous bosses. Granite and schist also crop out in places, dip E.S.E. at angles varying from 45° to 90°; altitude 15,000–17,000 feet.

Descending to Atuntsi we find chiefly mica-schists, and higher up limestones and slates. Atuntsi lies in a depression which is evidently a syncline. To the west rises a bulky outlier of the main divide, 15,600 feet above sea-level, composed chiefly of slates, with curious pillars of limestone cropping out on its east and west faces.

In the Mekong valley itself, purple and green slates are seen in the river bed, always standing on edge, and the same in the bed of the Salween; the dip seems to decrease as one ascends. In a gorge of the Mekong just south of Atuntsi we pass from north to south through (1) vertical slates striking N.N.W., (2) granite, (3) limestone (?) in a few miles. Just south of the last is an outcrop of coral limestone on the river bank. In the Mekong valley the schists and slates are everywhere almost vertical, the strike varying from N.N.E. to N.N.W. Altitude 7,000–9,000 feet.

At 10,000 feet on the Mekong–Salween divide the schists and slates met with were vertical, striking almost due south, giving a succession

of narrow gullies on the main spurs, separated by razor-edged walls of rock standing out like ribs. The Mekong–Salween divide is here capped by granite, with outcrops of grey slate, instead of by limestone. Further north are various metamorphic rocks. Altitude 15,000–17,000 feet. On the main spurs a succession of broken anticlines can sometimes be traced, causing the crests of the spurs, which are very steep-sided, to be jagged like a saw. Conglomerate was seen in one place at 17,000 feet.

In the valley of the Wi-ch'u, which is crossed *twice* before the Salween is reached, limestone and schists, dipping north at high angles, are met with.

In the Salween valley the rocks are mostly limestone and granite in the north (i.e. north of Atuntsi), limestone, slates, and schists further south. The river cuts its way through remarkable gorges of granite and limestone, in some places crystalline, and at one place there are conspicuous scarps of the latter rock, like old river gorges, a thousand feet or so above the river.

The summit of the next range to the west, the Salween–Irrawaddy divide, I have not yet crossed in this latitude, though I have several times seen its snowy peaks; but a hundred miles further south the great bulk of it is granite, with conspicuous cliffs and peaks of limestone cropping out lower down on the Burma side, and the same vertical slates reappearing in the bed of the 'Nmai-hka at least as far north as latitude 27°; still further north it appears to flow, like the Salween, through granite gorges.

Leaving the 'Nmai valley and continuing westwards to Hkamti-Loong (latitude 27°), we pass from the igneous rocks of the great mountain ranges to laterite and clays as the plain is approached, and finally to sands and alluvium on the plain itself, overlying a hard conglomerate which contains rolled pebbles of many igneous rocks. The plain is divided by three conglomerate[1] terraces of varying breadth, rising one above the other from the river and trending in a more or less north and south direction; they appear to be old river terraces, but their discussion is irrelevant here.

Southwards of Hkamti-Loong we find in sequence from north to south the following: (1) Gravel interstratified with sand, often iron-stained and showing current bedding; in places converted into conglomerate by the weight of superincumbent rock and the infiltration of water carrying iron salts in solution. (This is well seen in a *nulla*, the 'conglomerate *nulla*', three marches south of Hkamti.) I will digress here for a moment to comment on these interstratified sands and gravels. One cannot look at the upper Mekong in summer, its red flood hurrying along sticks and branches, and at the same river in mid-winter, its shrunken waters blue as the Mediterranean, without perceiving that a river which is largely fed by glaciers and melting snow, or one which flows through a region with marked dry and rainy seasons, may lay down strata of two distinct types. Summer and winter deposits may in such case be as sharply demarcated as the

[1] The conglomerate is not solid right through, but forms an irregular 'pan' at varying depths.

annual rings of summer and winter wood in a tree trunk, and may be put to the same use, namely, to determine how many years it has required to build a certain thickness. Summer layers would be characterized by greater thickness, coarser material, and plant debris, winter layers by sand and mud (glacier mud) without plant remains. In the case of a very big river flowing to the sea through a country the climate of which was not uniform, these results would be more or less vitiated owing to other causes, namely, (1) the creation of a reservoir of material at the mouth of the river, and (2) the effect of tides in sorting and delaying the deposition of material; moreover, the lower course of such a river is invariably sluggish and incapable of moving more than the finer materials of denudation. Thus, even if the sediment was deposited as quickly as it arrived, no reserve accumulating, the uniformity of the material in suspension and the selective influence of the tides would effectually mask any classification into summer and winter strata based on the appearances of the river in its upper course. Thus no such sequence would be detected in the case of such rivers as the Yangtze and Mekong, in spite of arguments founded on their appearance in the region of the parallel rivers, for these rivers are always muddy at their mouths, where there are great reservoirs of silt. But in the case of a river, glacier-fed or otherwise, pouring into a big lake in the monsoon region, if the river is not too long, and especially if it derives much water from melting snow in the spring, seasonal deposits might be conspicuous, and it is to such seasonal deposits that I ascribe the interstratified sands, gravels, and leaf beds of the Hkamti basin. To continue the enumeration of strata passed between Hkamti-Loong and Myitkyna, we have, after the sands and gravels: (2) silver-grey (due to the presence of white mica flakes), buff, and reddish sands with rounded quartz pebbles; friable earths; argillaceous sandstones; blue clays, and grey claystones, with leaf beds and nodules of iron pyrites. The materials are coarser in the north, gravels, conglomerates, and sands, finer in the south, claystones and friable earths, showing that the rivers flowed into the lake from the north. The numerous native iron-mines in this region probably owe their origin to the accumulations of vegetable remains. South of the Hkamti plain these soft rocks have been thrown up into a series of ridges running parallel to the river and to one another, from 3,000 to 5,000 feet above sea-level, cut across by rivers flowing from the main divide (the Irrawaddy–Brahmapootra divide, or further south, the Irrawaddy–Chinwind divide) in the west.

3. Crumpled mica-schists, produced from sandstones and giving rise to the same friable red earth (or clay) as is derived from the sandstones further north—in the bright sunlight this red earth is a burnt-ochre colour, and a beautiful feature of the scenery, where the dense jungle allows of its becoming visible; and bluish slates. The direction of dip varies between south and east, being generally about S.E. or E.S.E., at angles varying from 30° to nearly 90°.

4. In the bed of the 'Mali-hka just above the confluence, dark grey slates with quartz veins, dipping east at nearly 90°. These slates probably underlie the lake series, and seem to be identical

with the slates in the beds of the Mekong and Salween further north (i.e. in the north-east) and the oldest rocks in this region.

It will be readily recognized how complicated is the geology of this region and how difficult it will be to unravel, not only on account of the vast extent of country involved and the physical difficulties of travel, but also owing to the alterations and displacements of the strata consequent on the great irruptions of granite, which is found from the river-beds, 6,000 feet above sea-level, to the crests of the Mekong–Salween divide at 18,000 feet, and to the fact that the Burmese hinterland is covered with impenetrable jungle.

To sum up. Everything in the arrangement of the rocks throughout this region so far as I am acquainted with it, points to a synclinal structure, or more accurately fan structure, between the Brahmapootra and the Yangtze, induced by a pressure acting from west to east as the final phase of crust movement, which breached a continuous Sino-Himalayan axis, the result of a previous crust movement from south to north. The present hydrography of the region is due to a fusion of two sets of rivers which have become involved since the second phase of crust movement; the peculiar loops into which some of the rivers have been thrown must be ascribed partly to the buckling and twisting of vertical strata consequent on pressure acting at right angles to the dip, whereby rivers following the strike of the rocks have been thrown out of their course. Finally, there has been a rift formation in addition, due to a lateral tension strain, acting at right angles to the long axes of the synclines, or to a sagging of the anticlines with consequent rupture of the synclines. Complications have been introduced by the bursting through of enormous masses of granite, which have tossed aside and altered the sedimentary rocks. The whole of this region must once have been under water like the Hkamti plain, but in the east subsequent alteration has gone so far that there are no clays and sandstones left, and the further east one goes the greater is the metamorphism and crumpling of the rocks. Possibly the pressure which gave rise to these mountain ranges is still acting from the west, and the white mountains which lift up their heads so proudly will grow yet higher and grander; but the fires which blasted this corner of Asia are drawn, the great lakes are drained. Only the restless rivers still pour through the terrific breach in the Asiatic divide to the hot south, to be followed through the rent they had torn not less impetuously by the hordes of hardy northmen who, six centuries before Christ, overran the plains of Indo-China.

NOTICES OF MEMOIRS.

Artesian Water in Manitoba.[1] By J. B. Tyrrell.

FOR many years, in fact almost ever since Winnipeg has been a city, it has depended for its water supply on wells sunk through the impervious layer of Boulder-clay which underlies the city, into a bed of porous limestone from which water rises in great abundance. From these wells the city has been able to obtain

[1] From the *Canadian Engineer*, vol. xxvi, No. 15, p. 574, April 9, 1914.

a plentiful supply of water which, while containing a slight amount of mineral matter, is absolutely free from any hurtful bacteria, or from organic germs of any kind.

The porous limestone into which these wells are sunk, and from which the water rises, extends to the north and west beneath a layer of Boulder-clay, and rises to the surface in a number of places in the country between Lakes Winnipeg and Manitoba at elevations varying from about fifty to one hundred and fifty feet above the level of the prairie at Winnipeg. The rain falls on these bare rocky areas, as well as on the adjoining clay-covered country, but instead of flowing away in rills and streams, as it does on the clay-covered country, it at once sinks into the porous limestone and flows through this limestone southward and eastward until it finally reaches the surface either in the large springs north of Winnipeg or through the wells at the city of Winnipeg itself. The quantity that flows from these springs and wells is therefore largely limited to the amount of the rainfall on those portions of the surface where the porous limestone is uncovered. Where it is covered, as it is in many places, most of the water derived from the rain either stands in small lakes and evaporates from the surface, or drains off towards Lake Winnipeg or Lake Manitoba by the many streams which unwater the country.

The underlying porous limestone through which the water percolates on its way from the exposed areas north-west of Winnipeg to the wells in Winnipeg is a magnificent natural filter which is protected from contaminating influences throughout the populated parts of Manitoba by a thick covering of impervious Boulder-clay. No other city on the continent is provided by nature with such a filter, and no city could afford to duplicate it.

REVIEWS.

I.—Memoirs of the Geological Survey of England and Wales.

The Coals of South Wales, with special reference to the Origin and Distribution of Anthracite. By Aubrey Strahan, M.A., Sc.D., LL.D., F.R.S., and W. Pollard, M.A., D.Sc., F.I.C., assisted by E. G. Radley. 2nd ed. 8vo; pp. 78, with 10 plates. 1915. Price 1*s.* 6*d.* E. Stanford, Long Acre, or any agent for the sale of Ordnance Survey Maps.

WITH A MAP, reproduced from Plate IV by permission of the Controller of H.M. Stationery Office.)

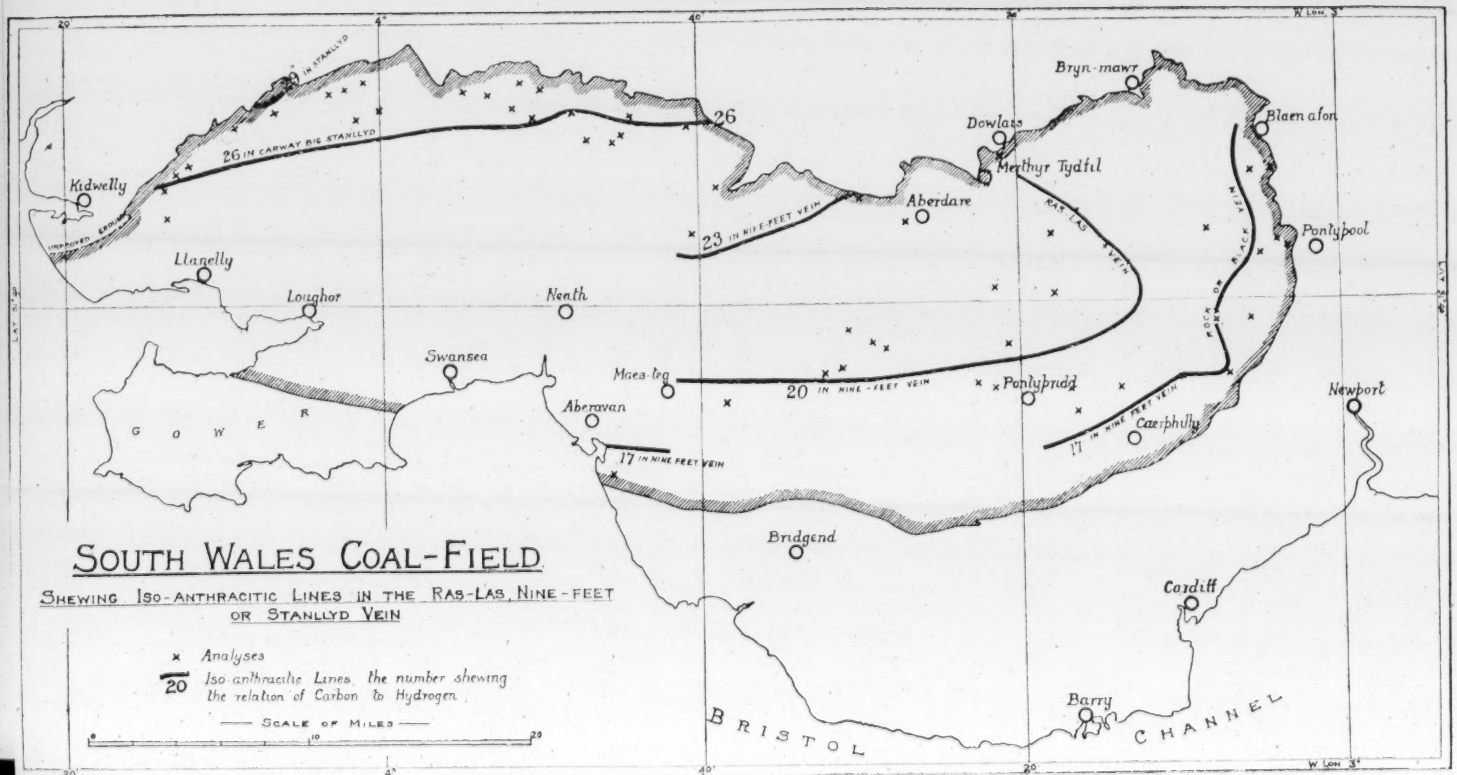
FOR a long series of years the energies of those geologists who are also chemists seem to have been so concentrated upon questions of crystallization and the differentiation of igneous magmas that the corresponding and equally interesting problems of continuous variation in the composition of beds of sediment have remained outside the scope of their activities. To the nation sedimentary rocks are at least as important as igneous rocks. To our industries they are even of greater importance; and to those who have been called in to help in mobilizing home resources of raw materials and providing manufacturers with efficient substitutes for sedimentary materials till lately imported in bulk from abroad, the failure to take stock of this whole class of the nation's resources has seemed a neglect which

requires to be taken in hand at once. Among sedimentary rocks there is no class so essential to commerce as coal, and among coals there are none of greater national importance than are the anthracites of South Wales. It is therefore only to be expected that when we seek the best available account of the composition of beds of sediment and the lateral variation of those compositions from place to place, we should find it in a publication of H.M. Geological Survey which deals with the coals of South Wales.

Ever since the days of De la Beche and Playfair (1848) the steam coal of the Navy has been a subject for chemical specification and research; but though analyses of coals from many localities have accumulated, the geological data concerning the samples were generally so little precise that until the present century the results of the analyses have hardly been dealt with by geologists and do not seem ever to have been employed to throw light upon the natural history of the rocks.

The Geological Survey Memoir on the Coals of South Wales was first published in 1908. Its main feature was the assembling of a great number of trustworthy and complete analyses of coals which had been collected, with proper precautions in sampling, from all the more important coal-seams, at localities which were distributed as widely as possible over the length, breadth, and thickness of the Coal-measures of the South Wales Coal-field. The analyses were all performed systematically, by standard methods, on samples collected by men whose business is not the buying or selling of the coal; and being all therefore strictly comparable with each other, they have proved of special value to those who are concerned with the commercial exploitation of the field. For the geologist, whose main concern is with the generalizations which emerge from the statistical treatment of these tabulated analyses, rather than with the figures themselves, it was the summarization of the analyses, each under the so-called "index of anthracitization" (a number obtained by dividing the percentage by weight of carbon by the percentage by weight of hydrogen contained in the coal), which marked the great advance.

Until the memoir appeared, the view that, in South Wales, anthracitization of the coals was an event contemporaneous with the deposition of the measures, was only one among several alternative hypotheses. Now, however, as the result of the field and laboratory work set forth in the memoir, this hypothesis has advanced to the foremost place, and the diagram maps, which show the iso-anthracitic lines for each of the more important seams or groups of seams over the coal-field, form an excellent demonstration of the forcefulness of the evidence which supports it. Iso-anthracitic lines are obtained by plotting, on separate maps for each coal-seam, the index of anthracitization for the samples of coal analysed, each at the geographical locality from which it was collected, and by drawing contour-lines among the 'spot-levels' so obtained. In each of the seams or groups of seams for which they are illustrated, the iso-anthracitic lines have come out as sweeping sub-parallel curves, which range about axes or centres peculiar each to the particular seam or group of seams which



Reproduced (greatly reduced) from the original map, published in the Geological Survey Memoir on *The Coals of South Wales, with special reference to the Origin and Distribution of Anthracite*. 2nd ed. (1915). By permission of the Controller of H.M. Stationery Office.

is the subject of the illustration, which centres are situate in some cases within, in others beyond, the present northern boundary of the coal-field. (See Map on p. 222.)

Assembling the alternative hypotheses for the purpose of destructive criticism, Dr. Strahan notes that in taking the view "that the differences between anthracitic and bituminous coals in South Wales are mainly due to original differences of composition" he was guided by four main considerations, the first three of which seem to be adequately proven by the diagrams given to show the distribution of iso-anthracitic lines. These four considerations may be summarized as follows: (1) "Groups of seams possess a certain individuality," and "in some there are local anthracitic areas of which no evidence appears in others . . . but bands of the same seam may show considerable differences of composition". (2) "Iso-anthracitic lines show no definite connexion with the faults and disturbances," and "though the strata may be vertical or even inverted and sharply folded as in Gower, yet the coal-seams retain the composition proper to that part of the coal-field". (3) "Anthracitization is obviously not connected with the existing outlines of the coal-field as determined by denudation," and "there is no connexion between anthracitization and depth from the present surface". (4) is based upon the consideration of the proportion of inorganic ash which remains when the coals are combusted. "The comparative freedom of anthracitic coals from ash" was "already brought out by Mushet's analyses" as long ago as 1840, but it has remained for the present generation to discover that when a sufficient number of Welsh coal analyses are assembled the percentage of ash rises "with fairly steady gradient from 1 per cent at the anthracitic end to more than 6 per cent near the bituminous end of the scale".

These four main considerations all point to an early date for the formation of the anthracite of South Wales, and if it be accepted that variation in the percentage of ash "cannot be due to subsequent alteration" of the coal it must follow that anthracitization took place contemporaneously with the deposition of the Coal-measures.

A fifth line of evidence, based upon the finding of certain "true pebbles" of coal (remanié from the breaking up of some already consolidated seam) among the sandstone pebbles which form the conglomeratic beds interstratified with the Pennant Grits of the Upper Middle Coal-measures, clinches the argument.

In the second edition of the memoir now before us the number of tabulated analyses has been increased to 321, which, with the inclusion of the results of direct determinations of the percentage of moisture and of the calorific value for forty-seven of the samples analysed, will make it by so much the more valuable to commercial men. The new samples have been collected during the recent revision of the maps of the coal-field, all under the standard conditions of sampling observed for those dealt with in the first edition. Of the 118 new analyses, some were done in the Survey laboratory and many by the staff of the Government laboratory: much credit is also due to Mr. C. A. Seyler, who, working first for and later in collaboration with the officers of the Geological Survey, has

been responsible for no less than 101 of the analyses now tabulated. So far as the geological conclusions are concerned, all the arguments put forward in the first edition are somewhat strengthened, and the net result of the revision is a greater precision in the location of the lines of iso-anthracitization in the charts for the various seams. In the letterpress we find additional comments by Dr. Pollard upon certain more modern methods of analysis introduced by American and other chemists since 1908, but for the sake of uniformity none of these has been adopted. In the last pages of the memoir Dr. Strahan allows himself to draw tentative conclusions concerning the physical geography in South Wales and Ireland in Carboniferous times, and we find it definitely suggested that it was some peculiarity of physical geography in South Wales and Ireland which led to the differentiation of the material in the coal-seams. "As the coast-line retreated northward the area of anthracite coal shifted and kept pace with it," and the rule "that each seam in any locality is less anthracitic than its predecessors . . . is a necessary accompaniment of the formation of anthracite at successive intervals at a more or less constant distance from a retreating shore-line".

Of the labour involved in the preparation of the memoir only those who have personal experience of quantitative analysis of coal are competent to judge. The general laws governing the "gradation into anthracite" in South Wales have been made clear, and even allowing for the unique opportunities offered by a coal-field which is in course of active development over almost the whole of its extent, it may be fairly claimed that this is no small accomplishment, a result certainly to be accounted as of "both scientific and economic value". What has been done for anthracite may be extended to other groups of sedimentary rocks, and if geologists who have adequate experience of the arts of chemistry, or chemists who have sympathy with the requirements of geology, can be persuaded to take up the work, further discoveries of equal scientific interest and of perhaps even greater advantage to the nation's commerce should reward their efforts. To such workers we commend the second edition of the Survey memoir on the Coals of South Wales as a model worth following when they present their results. W. G. F.

II.—The Geological Survey on the Mineral Resources of Great Britain.

IN the stress of a protracted war it behoves belligerent countries to take careful stock of their resources. The special reports by the Geological Survey on the Mineral Resources of Great Britain, of which three volumes have appeared—the first (pp. 59, 1*s.*) on Tungsten and Manganese Ores, the second (pp. 93, 1*s.* 6*d.*) on Barytes and Witherite, and the third (pp. 57, 1*s.*) on Gypsum and Anhydrite—are timely and very welcome. Some legitimate surprise may perhaps be felt that such obviously useful publications had not been issued long ago, before the cloud of war loomed and broke, but in this country the State was ever chary of assisting and stimulating industry, and the Geological Survey constitutes no exception to the general rule of Government departments. It is remarkable that for

many substances of vital importance either for or in connexion with the production of munitions of war we should have allowed ourselves to be entirely dependent on foreign sources. Tungsten is a case in point. Practically all the ore is produced in the British Empire, yet it was all shipped to Germany and worked up there. The country is, however, now awake to the danger of allowing key industries to be entirely in hands which might become hostile. Another urgent reason for making the most of resources actually in the country is the necessity for restricting our imports as much as possible. Intelligent prospecting might bring to light mineral ores from which might be produced many chemical substances at present imported and fast growing scarce.

All the volumes follow very similar lines. The chemical composition and physical properties of the minerals supplying the substances in question are described very briefly; this section might with advantage have been expanded so as to make the identification of the minerals easier for those not skilled in the subject. A section follows on the commercial uses, with statistics, and the method of treatment. The mode of occurrence is then discussed, and the principal mines are described in some detail. The list of localities is not exhaustive: possibly none were included which were not represented by specimens in the Museum in Jermyn Street.

Of the substances dealt with, tungsten and manganese are largely used for alloying steel, the former having also an extensive use for the filaments of incandescent electric lamps; barytes is required in the preparation of white paints and for wall-papers, while witherite is the principal source of barium compounds; gypsum furnishes the familiar plaster of paris, and celestine and strontianite are the sources of the strontium used in sugar refining.

III.—Lower Palæozoic Fossils of Burma.

Supplementary Memoir on new Ordovician and Silurian Fossils from the Northern Shan States. By F. R. Cowper Reed. Palæontologia Indica, n.s., vol. vi, Mem. 1, viii + 98 pp., 12 pls., 1915.

THE memoir to which this is supplementary was published in December, 1906, under the title *The Lower Palæozoic Fossils of the Northern Shan States, Burma*, by F. R. C. Reed, *with a Section on Ordovician Cystidea*, by F. A. Bather. In that memoir fossils were described from the Naungkangyi and Nyaungbau Beds of the Ordovician, and from the Namhsim and Zebingyi Beds of the Silurian. From those beds further fossils are now described, but the chief interest lies in those from two fresh sets of beds which are, on their evidence, referred to Lower Silurian and Middle Ordovician.

The stratigraphical succession, from above downwards, is as follows. Silurian: Zebingyi Stage, transitional to Devonian; Namhsim Stage, consisting of the Upper or Kônghsa Marls, with *Phacops shanensis*, correlated with Lower Ludlow, and the Lower or Namhsim Sandstones, with *Phacops longicaudatus*, var. *orientalis* and *Illænus namhsimensis*, n.sp., correlated with Wenlockian; and the

Panghsa-pye Stage, consisting of an Upper or Graptolite Band and a Lower or Trilobite Band (to these we shall recur). ORDOVICIAN: Nyaungbaw Limestones with "*Camarocrinus asiaticus*"; the Upper Naungkangyi Beds, comprising the Hwe Maung Purple Shales; the Lower Naungkangyi Beds, with the rich Cystid fauna of Sedaw, probably Llandeilian; and the Ngwetaung Sandstones with a species of *Orthis*.

The rocks of the new Panghsa-pye Stage are of interest, not merely from their richness in organic remains, but from the occurrence of graptolites in the upper beds. These, as determined by Dr. Gertrude Elles, indicate three horizons, two of Lower Llandovery age, and the third suggestive of the Wenlock Shale. From the lower Trilobite Band are recorded some plates assigned to *Turrilepas*, but, since no figures are given, it is impossible to decide whether this reference would be correct according to more recent views.

The Upper Naungkangyi Beds, of which the Purple Shales may be a local facies, are exceedingly fossiliferous and have yielded many new species. The trilobites on the whole indicate an horizon corresponding with Stage C of the Baltic Provinces, and Ashgillian types do not appear. In both sets of beds there occurs a new lamellibranch of the Family Vlastidæ, which Dr. Reed names *Shanina vlastoides*. The trilobite *Pliomera ingsangensis* Reed, has also been found in both facies, and is now made the type of a new subgenus *Encrinurella*. Of this subgenus no definite diagnosis is given, but the main diagnostic characters appear to reside in the glabella, which resembles that of *Encrinurus*. On p. 97 Dr. Reed notices "the absence of cystideans" from the Hwe Maung Purple Shales; but Mr. T. H. D. La Touche, to whom the distinction of these beds is due, said: "the more argillaceous portions of the rock are highly fossiliferous, containing large casts of fragments of crinoid stems, cystidean plates, etc." (Mem. Geol. Surv. India, xxxix, part 2, p. 92, 1913).

Reference to Mr. La Touche reminds us that in the same paper (p. 65) he stated definitely, what those familiar with the literature had already assumed, namely that *Camarocrinus asiaticus* Reed, was identical with *Echinosphærites kingi* Noetling (see GEOL. MAG., 1892, p. 521). The reference of *Camarocrinus* to *Scyphocrinus* was also made clear at least as early as 1907. From this it would appear that *Camarocrinus asiaticus* should be known as *Scyphocrinus kingi*. It is, however, very doubtful whether Noetling's name can be accepted, so that we may perhaps correctly speak of *Scyphocrinus asiaticus*.

Dr. Cowper Reed is to be congratulated on the enthusiastic industry with which he tackles these large and varied collections of fossils. The same congratulations can hardly be extended to his would-be readers. It may be that, in the present case, the War has increased the natural difficulty of correcting proofs from a printer in Calcutta; but misspellings and misplaced commas are minor evils. What is to be deprecated seriously is the impression conveyed by so many of these large memoirs, that they are notes jotted down *currente calamo* and sent to the press without further revision. From too many sentences the author's meaning can only be extracted by a prolonged process of

interpretation. Till Dr. Reed shows more respect for his public, his erudition, energy, and ability will not receive the recognition that is their due.

IV.—The Pliocene Floras of the Dutch–Prussian Border. By Clement Reid, F.R.S., and Eleanor M. Reid, B.Sc. Mededeelingen van de Rijksopsporing van Delfstoffen, No. 6. pp. 180, with 4 text-figures and 20 photographic plates. 's Gravenhage: M. Nijhoff. 1915. Price fr. 16.50.

MR. AND MRS. REID have developed on lines of their own the study of the fossil fruits and seeds of the Tertiary floras. They have worked for many years on the Pleistocene and Pliocene deposits of Britain "in the hope of obtaining some approximate measure of geological time, some idea of the succession of climatic changes, and some insight into the origins and migrations of successive faunas and floras". As a result of their work we have become acquainted with a sequence of small floras working backwards from the comparatively modern Roman deposits through Celtic, Neolithic, Glacial, Interglacial, and early Glacial strata to the latest Pliocene stage represented in the Cromer Forest-bed. But as in Britain there is here a break in the succession, the earlier Pliocene deposits being marine and containing no plants, the authors have been forced to look abroad for the continuation of the history of the Pliocene flora of North-Western Europe, and hence have undertaken the examination of the Pliocene flora which has been recently discovered at Limburg on the Dutch–Prussian border. In view of the remarkable results obtained from the study of the Upper Pliocene flora of Tegelen, which were published in 1907, the publication of the detailed account of Mr. and Mrs. Reid's further work in the same region has been awaited with much interest.

The Reuverian flora, as the authors style it, from the name of the principal locality, is found to be of an older type than the Tegelian, though many plants are common to the two. It indicates a warmer climate, and is classed as Middle Pliocene. Up to the present nearly 300 species have been examined; of these the authors have been able to suggest the botanical position of about 230 "with some degree of certainty", and of a lesser number "with considerable certainty".

The results arrived at are of great interest. The trees and shrubs, which form the most peculiar and striking element in the flora, show a close relationship with the mountain flora of Western China at the present day. Thus, among the species found in Limburg are *Gnetum scandens*, *Magnolia Kobus*, *Zelkowa Keaki*, and other present-day Chinese species. Others occur which, belonging to genera now extinct in Europe, are still represented in China by closely allied species; such is *Meliosma europæa*, closely allied to *M. Veitchiorum* of the mountains between China and Tibet. Again, when the genus in question is common to both Europe and China, it is often a Chinese or Japanese species that most resembles the Reuverian plant. The Reuverian flora suggests a mean temperature similar to that of Southern France to-day, but the Chinese alliance is more strongly

marked than that with the existing flora of the Mediterranean area. The flora as a whole was probably much richer in species than the present-day Central European flora, and was possibly comparable in variety, in the number of its species, and in the abundance of its trees and shrubs with the present-day flora of Western China.

Coming to general considerations of plant-distribution, the authors, developing the now well-known resemblance between the Eastern North American and East Asiatic floras, conclude that the Reuverian fossils indicate one of three great streams of migration southwards from a common centre in the north, the other two being the Chinese and North American. The two latter found an open route to warmer regions and survived; the Reuverian, on the other hand, found a barrier of seas, deserts, and mountains and perished under the rigorous climatic conditions before which it was retreating.

The greater part of the volume is occupied with a detailed systematic description of the fruits and seeds which have been separated from the lignitic material. Some botanists may find points of issue with Mr. and Mrs. Reid in their general conclusions or in some of their specific determinations, but all must admire the wonderful patience, industry, and skill of which the present work is a monument. The hundreds of beautiful photographic reproductions of the objects described are alone of inestimable value. We hope that the authors will be able to continue their exploration of these interesting deposits.

A. B. R.

V.—Geological Survey of Western Australia.

Bulletin No. 61, *An Outline of the Physiographical Geology (Physiography) of Western Australia*, by J. T. Jutson, is a deliberately educational volume designed to aid the citizens of the State to a juster appreciation and a greater knowledge of the land in which they dwell. The treatment throughout is thoroughly modern, and owes much to the American school of geographers headed by W. M. Davis. West Australia is a country of extreme geological antiquity, and its great interior plateau, formerly a peneplane, is now in a cycle of desert erosion. It presents a series of unique physiographical problems, of which, notwithstanding the present work, only the fringes have been touched. Mr. Jutson has produced a work of extreme interest, readable throughout, which will certainly form the starting-point for all future investigation of this subject in Western Australia.

Bulletin No. 56, *The Geology of the Country between Kalgoorlie and Coolgardie*, by C. S. Honman, serves as a connecting link between previous bulletins describing the country around the above-mentioned mining centres. The rocks consist of a series of inclined and folded metamorphosed sedimentary rocks, probably Pre-Cambrian in age, with intercalated beds regarded as volcanic rocks. The whole series is invaded by basic and acid intrusive rocks, but, unlike the neighbouring areas, it contains few ore-deposits. The scale on which geological surveys are carried out in our great Dominions

is exemplified in Bulletin 57, *A Geological Reconnaissance of a portion of the Murchison Goldfield*, by H. P. Woodward. We are told that the area dealt with embraced 3,300 square miles, and that the work was carried out chiefly in 1912 with some unavoidable interruption. The country consists chiefly of granite, with ancient crystalline schists, and shows wonderful examples of arid erosion, many of which are figured. The bulletin contains an account of the economic geology of the area, including two tin fields, an occurrence of emeralds, and aboriginal ochre mining. The emeralds are derived from pegmatite veins cutting mica-schists, and the occurrence is of value as the gem is now very scarce.

Bulletin No. 59 is a collection of Miscellaneous Reports containing eighteen short papers, mostly preliminary observations on various ore-bearing areas of the State, issued in this form so as to ensure prompt publication of the valuable mining information they contain. Gold is, of course, the main quest; but occurrences of tin, lead, copper, coal, and rare metals are also dealt with in this bulletin. There are also two petrological papers, and one on Western Australian meteorites.

G. W. T.

VI.—On certain Channels attributed to Overflow Streams from Ice-dammed Lakes. By Professor T. G. Bonney, F.R.S. pp. 44. Cambridge: Bowes & Bowes. 1915. Price 1*s*.

ALTHOUGH Professor Kendall's explanation of the so-called overflow channels of the Cleveland district has been applied to similar phenomena in East Lothian, Cumberland, Dublin, and elsewhere, a number of objections of a general character have been raised from time to time. In the Presidential Address to the British Association in 1910 Professor Bonney stated the difficulties involved in the "land-ice theory", and in the pamphlet under review these difficulties are reiterated and the result of a detailed examination of several of the above-mentioned localities discussed. Although at the present day marginal lakes are uncommon, most of the Alpine examples being small and possessing no overflow channels, certain criteria such as beaches, deltas, floor-deposits, and overflow channels are considered to be indicative of the former presence of such lakes. In the case of Glen Roy the evidence consists mainly of the first two, but in the North of England the last is the only significant criterion.

Professor Bonney holds that the 'railway cutting' trenches must have been cut by mature rivers, and that their form is not such as would be expected from lake overflows, even where the latter would carry much debris. He prefers to consider them as the "relics of ancient, sometimes very ancient, valley systems and not such modern features as the glacial theory demands". Various facts seem to favour this hypothesis: for example, the channels sometimes occur in an aligned series, while they are often cut by later transverse streams. Again, overflows would tend to be spasmodic, while the resultant trenches would, like Alpine sub-glacial streams, tend to be V-shaped. The absence of deltas seems significant, since overflow streams would

be heavily charged with debris; Thoroddsen has recently described the blocking-up of fiords in Iceland by the debris carried by *jokull-vatn*.

The glacial theory of the in-and-out channels is also unsatisfactory. In the case of a stream flowing between a glacier and a hillside it is very probable that the latter would be much more resistant than the former, so that the stream would tend to cut its way into the ice and to lower the level of its bed. Thus, instead of a flat 'bench' along the hillside, the latter would be in the form of a shelving slope working gradually towards lower ground. Professor Bonney offers two alternative explanations: one that the 'out' portions are the remnants of valleys, one wall of which has been worn away by marine erosion; the other, that one bank has been greatly steepened by warping subsequent to the formation of the channels.

The widespread occurrence of these dry valleys and the variety in form render it probable that no single explanation satisfies all the examples. Some must be assumed, at present, to be due to 'overflows', as it is impossible to correlate them with any former drainage systems; others, such as the large cross-cut near Cader Idris, strongly favour the view that such channels may originate without the assistance of glacier lakes. It also seems possible that some may arise by the re-excavation or clearing out of older filled-up valleys by the action of glacial streams. This would explain why these pre-glacial valleys are free of glacial material and at the same time satisfy the glacialists who maintain that the form of the trenches is that which would be expected from the action of heavily laden streams with comparatively low gradients.

A. S.

VII.—Geology and Ore Deposits of Copper Mountain and Kasaan Peninsula, Alaska. By C. W. Wright. U.S. Geol. Surv. Prof. Paper No. 87, 1915. pp. 110, with 22 maps and plates.

THE Prince of Wales Island, the largest of the southern islands of Alaska, is separated from the mainland by Clarence Strait, which with its numerous branches breaks South-Eastern Alaska into numerous islands and peninsulas. The network of fiords extends northward from the Portland Canal. The country shows abundant signs of glaciation, but has no existing glaciers, and owing to its mild moist climate, its latitude of only 55° to 56°, and its long summer days, it is covered with a vegetation which, though mainly coniferous, is often as dense as tropical jungle. These forests have greatly hampered the geological survey of the area, which has been stimulated by its valuable copper deposits. The survey by Messrs. F. E. and C. W. Wright shows that the country has an Archæan foundation, on which rest Silurian, Devonian, and Carboniferous sediments. During Lower Mesozoic times it was intruded by a great series of plutonic rocks, and extensive andesitic lavas were discharged on the surface. As usual in Alaska, the chief Kainozoic formation is a great series of continental sediments of Eocene age; they were followed by basaltic eruptions, some of which have taken place in post-Glacial times.

The complex of fiord channels and valleys is shown by the geological maps, especially by that of the Kasaan Peninsula, to be quite independent of the older grain of the country; the arrangement of the fiords is inexplicable on any theory of glacial erosion, and is only explicable by their origin along intersecting Upper Kainozoic fractures. The ore deposits are numerous bodies of copper ores in the contact zone, where granite has been intruded into limestones. The ores occur in shoots, which though near the contact are not exactly along it. The memoir is a valuable addition to the economic geology of Alaska.

VIII.—Revision of the Tertiary Mollusca of New Zealand, based on Type Material. By H. Suter. New Zealand Geol. Surv. Pal. Bul. No. 3, pt. ii, 1915. pp. vii, 69, with 9 plates.

MR. HENRY SUTER, the consulting palæontologist to the Geological Survey of New Zealand, has completed his useful redescription of a series of types of New Zealand Kainozoic Mollusca of species founded by Hutton, Mr. E. de C. Clarke, Dr. J. A. Thomson, and Professor Marshall. He has established one of McCoy's list names as a new sub-species. The revision is illustrated by nine excellent plates. The species range from the Miocene to the Pleistocene; the majority are Pliocene. Mr. Suter accepts the Oamaru Beds as Miocene, which is consistent with the conclusions of McCoy and Chapman as to the age of the corresponding fauna in South-Eastern Australia. On p. 37 he, however, leaves the Australian range of *Bathytoma haasti* as Eocene, whereas from the localities cited it would also be more correctly included in the Miocene.

IX.—The Inorganic Constituents of Echinoderms. By F. W. Clarke and W. C. Wheeler. U.S. Geol. Surv. Prof. Paper No. 90 L, 1915, pp. 191–6.

MESSRS. CLARKE AND WHEELER have extended their interesting researches on the composition of the Crinoid skeleton to the Echinoids and Stelleroids. They find by nine analyses of Echinoid plates that the amount of carbonate of magnesium in the shell ranges from 6 to 13½ per cent, and that the geographical distribution of the specimens shows that the proportion of magnesia is inversely to the latitude. A series of analyses of the joints of the Starfish and Ophiuroids shows the same conclusion; the proportion of magnesium carbonate ranges from 7·79 to over 14 per cent, and as a rule the proportion is highest in specimens from the warmest seas. A limestone therefore formed of the remains of Echinoderms which had grown in a warm sea would give rise to a magnesian limestone. The authors announce their intention of extending their investigation to other marine invertebrates to determine whether their skeletons show the same distribution of magnesia, so that magnesium sediments would naturally be deposited more in warm than in cold climates.

X.—Brief Notices.

1. East Lothian. By T. S. Muir. Cambridge County Handbooks. pp. 177. 1915. Price 1*s.* 6*d.* net.

THIS useful little volume maintains the high standard of the now familiar series to which it belongs. The county includes parts of the Central Plain and of the Southern Uplands, and boasts a picturesque coast, thus affording scope for a highly interesting geographical study.

2. Victorian Trilobites.—In his series "New or little-known Victorian Fossils in the National Museum", Mr. F. Chapman has recently published a description of some Trilobites from the Yeringian (Upper Silurian) beds. These include new species of *Goldius*, *Cyphaspis*, and *Calymene*. Other genera represented are *Proëtus*, *Cheirurus*, and *Phacops*. In adopting De Koninck's name *Goldius*, 1841, in place of Goldfuss' *Bronteus*, 1843 [*not* 1834], Mr. Chapman might have given a reference to the original publication. Life-size photographs of the specimens are reproduced, and when these fail in clearness an enlarged drawing is added—a very good plan.

3. *Equisetites* in Jurassic Shale, Wonthaggi, Victoria.—Under the name *Equisetites wonthaggiensis* Mr. F. Chapman describes the tuberous underground shoot of an equisetalean found in Jurassic shale from a boring at Wonthaggi, Victoria. Though *Equisetites* has previously been described from South Gippsland, this is the first record of this particular structure from Australia (Rec. Geol. Surv. Victoria, vol. iii, p. 317).

4. The Oil and Gas Fields of Ontario and Quebec. By Wyatt Malcolm. Canada, Department of Mines, Geological Survey, Memoir 81, No. 67 Geological Series, Ottawa, 1915. pp. ii+248.

IN this memoir the author sets forth concisely the geological conditions existing in the southern parts of Ontario and Quebec underlain by sediments which have suffered little disturbance. The most important oil- and gas-producing fields lie in South-Western Ontario. The oil pools of Oil Springs and Petrolia, opened fifty years ago, occur in the Onondaga (Coniferous) formation, but gas and oil have been found in the Salina (Onondaga), Guelph, Clinton, and Medina formations. There has recently been a rapid decline in the production of oil in spite of the discovery of new pools, but the gas production has increased rapidly.

5. Coal Fields and Coal Resources of Canada. By D. B. Dowling. Canada, Department of Mines, Geological Survey, Memoir 59, No. 55 Geological Series. pp. viii+174. Ottawa, 1915.

THIS memoir is reprinted with some additions from the report on the Coal Resources of the World presented to the Twelfth International Geological Congress. Canada appears to have large reserves of coal, but much of it is not available for the commerce of the British Empire. Large supplies of bituminous and sub-bituminous coals exist in the western interior, and to a lesser extent on both

coasts. The fields in Manitoba and Southern Saskatchewan supply lignitic coal well adapted for domestic use. The extensive coal-fields of Alberta, containing coals of a wide range of character, form Canada's greatest coal reserve. The interior of British Columbia contains many coal areas.

6. The Position of the Vibration Plane of the Polariser in the Petrographic Microscope. By F. E. Wright. Journ. Washington Acad. Sci., v, pp. 641–4, 1915.

IN petrographic microscopes with fixed polarizers the plane of the transmitted light is parallel to either the vertical or the horizontal spider-line of the eye-piece. The better position is that in which most light is transmitted. The light from the sky is always partially polarized, the amount varying with the distance from the sun's position, and further effect is produced by the reflection at the substage mirror. The second factor was found to be negligible. The first, however, is important, and to obtain the best illumination the observer should set the plane of the polarizer parallel to the vertical spider-line in the early morning and late afternoon, and at right angles thereto at midday, but, since the intensity at midday is so much greater than when the sun is low, the better position for a fixed polarizer is for the plane to be parallel to the vertical spider-line of the eye-piece.

7. A Simple Device for the Graphical Solution of the Equation $A = B.C$: a Geological Protractor. By F. E. Wright. Journ. Washington Acad. Sci., vi, pp. 1–7, 1916.

BY the use of reciprocals the variables may always be taken as less than unity. Rectangular co-ordinates, together with an arm revolving about the origin, are used in conjunction with squared paper, the scales being varied to suit the particular equation. The geological protractor is a particular form: from it the apparent dip of a bed can be read off directly for any angle of dip of stratum and for any azimuth of vertical section.

8. The Correlation of Potassium and Magnesium, Sodium and Iron, in Igneous Rocks. By Henry S. Washington. Proc. Nat. Acad. Sci., i, pp. 574–8, 1915.

THE correlation of the elements has not yet received much study except the relation based upon silicity. It appears that in igneous magmas potassium and magnesium, and sodium and iron, tend to vary together, the evidence being of two kinds—petrological and mineralogical.

9. Pressure as a Factor in the Formation of Rocks and Minerals. By John Johnston. Journal of Geology, xxiii, pp. 730–47, 1915.

GENERALLY the so-called physical changes (e.g. the melting-point of a pure substance) has been overestimated as compared with the influence of pressure on chemical changes. Change of effective pressure will in general alter the configuration of the various fields of stability in a system, but the effect will not be marked unless the concentration of one of the components changes appreciably with the change of pressure. In any discussion of the

course of crystallization from a complex magmatic system the mode in which the effective pressure varies must be considered as well as the mode of cooling, for change of pressure may affect the order of crystallization.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *February* 23, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read :—

"On the Origin of some River-Gorges in Cornwall and Devon." By Henry Dewey, F.G.S. (Communicated by permission of the Director of H.M. Geological Survey.)

In North Cornwall, near Tintagel, there is an area of peculiar topography characterized by the presence of an upland plain or plateau. The plateau is dissected by deep gorges, with their walls scarred by potholes through which the rivers flow in a series of waterfalls, cascades, and rapids.

This plateau is terminated inland by degraded cliffs rising abruptly from 400 feet above sea-level, while the plain slopes gently to the recent sea-cliffs, mostly over 300 feet high. The plateau has been cut across rocks of different degrees of hardness, and is overlain by deposits of detritus and peat. Wherever the plain occurs the scenery is featureless, and the land boggy and waterlogged.

The widespread occurrence of this plain over Cornwall and Devon at a uniform height suggests that in its final stages it was a plain of marine erosion. The author accepts Mr. Clement Reid's conclusion that its date is not later than Pliocene. Its uplift in post-Pliocene times led to rejuvenescence of the rivers, initiation of coastal cascades, and the production of gorges aided by the formation of potholes.

At Lydford, on the western flank of Dartmoor, the uplift led to the diversion of the Lyd by a stream that breached the valley-side and tapped the head-waters of the river.

A small stream, the Burn, now flows past Was Tor and Brentor, through the valley formerly occupied by the Lyd. The shortened journey to the lowlands bestowed such enhanced cutting-power upon the river that it quickly incised a chasm through which it now flows more than 200 feet below the base of its former valley; while a tributary enters as a waterfall from a hanging valley near Lydford Junction.

The elevation of the land also led to formation of gorges of similar character in other upland plateaux. These plateaux have been described by Mr. Barrow in the Quarterly Journal of the Geological Society, and reference is made to them by the author in connexion with the effects upon them of the uplift.

There are thus in Cornwall and Devon two characteristic types of scenery, to which in great part these counties owe their charm. Wide featureless plains covered with heath and marshland and dominated by tors and crags, on which the drainage is sluggish and vague,

alternate with deeply incised rocky ravines where rivers flow as rapids and cascades. These two types mark successive periods of erosion. Post-Pliocene uplift gave such increased cutting-power to the rivers that they quickly incised chasms in their former valleys, employing while so doing the activity of waterfalls and rapids.

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2. *March* 8, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The President referred with regret to the death, on March 3, of Professor John Wesley Judd, C.B., LL.D., F.R.S., Past President of the Society. He spoke of the value of Professor Judd's contributions to geological science, and of his eminence as a teacher of the science, and stated that the Society was well represented at the funeral.

Dr. Aubrey Strahan, F.R.S., Director of H.M. Geological Survey, exhibited and described briefly a set of specimens from the Western Front, illustrating the character of the rocks in which trenches, tunnels, etc., are being dug. They included specimens from the Cretaceous and Tertiary formations showing remarkable similarity in characters to the contemporaneous formations in Britain.

The following communication was read:—

"Fossil Insects from the British Coal-measures." By Herbert Bolton, M.Sc., F.R.S.E., F.G.S., Reader in Palæontology in the University of Bristol.

The author describes six insect wings found in the Coal-measures of Northumberland, Lancashire, and South Wales. Three of these have been previously named, but not described in detail; the remaining three are new to science.

Ædœophasma anglica, Scudder, has been examined in detail, and is now regarded as a primitive type of the Proto-Orthoptera, in contradistinction to Scudder's view that it is a Protophasmid, and to that of Handlirsch, who had removed it to a group of unplaced Palæodictyoptera.

Palæodictyopteron higginsi is shown to be related to the Dictyoneuridæ.

A new genus and species is created for a finely preserved wing, intermediate in character between the Dictyoneura and *Lithomantis*.

Among the varied fauna obtained from ironstone nodules in the Middle Coal-measures at Sparth Bottoms, Rochdale (Lancashire), is a basal fragment of a wing recognized as a new species of *Spilaptera*, and this is now described.

An unusual type of wing from the Northumberland Coal-field is very suggestive of the Protodonata, and is described as a representative of a new genus and species.

The author also discusses the Proto-Orthopterous affinities of *Pseudofouquea cambrensis* (Allen).

3. *March* 22, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

Dr. A. Smith Woodward, F.R.S., V.P.G.S., exhibited specimens of the problematical ichthyolite, *Cœlorhynchus*, from an Eocene deposit in the Ombialla district, Southern Nigeria, and discussed the nature of this fossil. Microscope sections of the well-preserved Nigerian specimens confirmed W. C. Williamson's determination that *Cœlorhynchus* is an essentially dermal structure. A similar section of part of the rostrum of the teleostean fish *Blochius*, from the Upper Eocene of Monte Bolca, near Verona, showed an almost identical structure. The precise nature of this rostrum remained to be determined, but there could be no doubt that the so-called *Cœlorhynchus* is the corresponding part either of *Blochius* or of an allied genus.

The following communication was read:—

"The Pseudo-Tachylyte of Parijs (Orange Free State) and its Relation to 'Trap-Shotten Gneiss' and 'Flinty Crush-Rock'." By S. James Shand, D.Sc., F.G.S., Professor of Geology in the Victoria College, Stellenbosch (S.A.).

The rocks which are here described as 'pseudo-tachylyte' occur in irregular veins in the granite-gneiss of Parijs (O.F.S.); they formed the subject of a communication to the Society on November 18, 1914, which has since been withdrawn. The author first regarded them as igneous intrusions; in the account now presented he compares and contrasts these rocks with the 'trap-shotten gneiss' of India and with 'flinty crush-rocks' from Scotland, Argentina, and Namaqualand. The veins are utterly irregular in form, dip, and strike; they freely branch and anastomose, but not uncommonly terminate blindly. The material consists of a very dense black base, holding numerous rounded and subangular fragments of granite; these are sometimes so numerous that the base is reduced to the rôle of a mere cement between the rounded boulders. With regard to their microscopic characters, the rocks fall into three types, one of which is very opaque and almost without individualized grains or crystals, while the others represent different stages of crystallization of the first type. It is shown that the production of the veins involved a temperature sufficient to melt the felspar of the granite, and that there has been extensive recrystallization of felspar in the form of spherulites and microlites, and also of prisms of hornblende. In this evidence of very high temperature, and in the entire absence of shearing phenomena in the granite, the pseudo-tachylyte of Parijs differs from all known crush-rocks and has affinities rather with pitchstones and tachylytes. Among the crush-rocks of Scotland, however, the author (following Clough, Maufe, and Bailey) recognizes a passage from the clearly mylonitic type to a type in which fusion has been practically realized; the latter material is closely similar to the first of the Parijs types. A chemical analysis of the pseudo-tachylyte shows that the total composition is practically that of a granodiorite, and is such as might correspond to an average of the very variable dark gneiss in which the veins occur.

It is suggested that a 'melt' of granite, produced by mechanically developed heat arising from the sudden rupture of the granite, would

differ in certain respects from a normal magma of granitic composition, and it is thought most likely that the veins represent the solid equivalents of such a melt.

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4. *April 5*, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The President announced that the Council had awarded the proceeds of the Daniel Pidgeon Fund for the present year to John Kaye Charlesworth, M.Sc., Ph.D., F.G.S., who proposes to conduct researches in connexion with the Glaciation of Donegal.

The following communication was read :—

"The Picrite-Teschenite Sill of Lugar (Ayrshire) and its Differentiation." By George Walter Tyrrell, A.R.C.Sc., F.G.S.

This sill occurs near the village of Lugar in East Central Ayrshire, and is magnificently exposed in the gorges of the Bellow and Glenmuir Waters, just above the confluence of these streams to form the Lugar Water. It has a thickness estimated at 140 feet, and is intrusive into sandstones of the 'Millstone Grit'. The contacts consist of a curiously streaked and contorted basaltic rock, passing at both margins into teschenite. The upper teschenite, however, becomes richer in analcite downwards, and ends abruptly at a sharp junction with fine-grained theralite. The lower teschenite becomes somewhat richer in olivine upwards, but passes rapidly into hornblende-peridotite. The central unit of the sill is a graded mass beginning with theralite at the top and passing gradually into picrite, and finally peridotite, by gradual enrichment in olivine and elimination of felspar, nepheline, and analcite.

The field detail of the Bellow, Glenmuir, and other sections is given in part ii of the paper; and the petrographic detail, with several chemical analyses, in part iii. A unique rock, named lugarite in 1912, with 50 per cent of analcite and nepheline, occurs as an intrusion into the heart of the ultrabasic mass of the sill. Part iv deals with the special significance of this sill in petrogenetic theory. The mineral and chemical variations are described and illustrated by diagrams. It is shown that the average rock of the sill, obtained by weighing the analyses of the various components according to their bulk, is much more basic than the rock now forming the contacts. Hence, assuming that the sill is a unit and represents a single act of intrusion, the main differentiation cannot have occurred in situ. Other special features of the sill are the identity and banding of the contact rocks, its asymmetry, the density stratification of the central ultrabasic mass, and the sharp junction between the upper teschenite and the underlying theralite.

The theory is advanced that the differentiation units were produced by the process of liquation, but that their arrangement within the sill took place under the influence of gravity. There are sharp interior junctions between a unit consisting mainly of calcic ferromagnesian silicates and a unit consisting mainly of alkali-alumina silicates with water, the former giving rise to the central ultrabasic stratum and the latter to the teschenites. These partly immiscible

fractions arranged themselves according to density. Then within the central ultrabasic stratum there was a subsidiary gravity stratification—due to the subsidence of olivine crystals, giving rise to the graded mass described above. If differentiation had occurred subsequent to the arrival of the sill in the position that it now occupies, the contact rocks should have the same composition as the average rock of the sill. This, however, is not the case, as the average rock has the composition of an almost ultrabasic theralite, entirely different from the teschenites of the contacts. Hence it is believed that, after forming contact-sheaths of theralite, and undergoing gravity stratification subject to liquation, the intrusion activity was renewed, and the sill was moved on along bedding-planes into cold-rocks, leaving its contact-sheath behind adhering to the old contacts, and establishing new contacts with its upper and lower teschenite-layers. Here crystallization began, and, by the subsidence of olivine, the subsidiary gravity stratification of the central ultrabasic layer was effected. The extraordinary flow-banding shown by the contact rocks affords confirmation of the renewed movement thus postulated.

In conclusion, the sill is compared with five other teschenite-picrite sills in Scotland, those of Ardrossan, Saltcoats, Blackburn, Barnton, and Inchcolm.

II.—Mineralogical Society.

March 21, 1916.—W. Barlow, F.R.S., President, in the Chair.

Dr. J. W. Evans: A new Microscope Accessory for use in the determination of the Refractive Indices of Minerals. The accessory—a diaphragm with narrow slit adjustable in width—when placed in the primary focus of the objective or any point conjugate with it, serves several useful purposes. If placed parallel to the boundary between the two substances whose refractive indices are to be compared by the Becke method, it gives better results than an iris diaphragm. In the case of doubly refractive sections or grains in which an axis of optical symmetry lies at right angles to the microscope axis, the slit is placed parallel to the former axis, so that the paths of all the rays of light traversing it lie in a plane of optical symmetry and one direction of vibration is always parallel to the axis of optical symmetry, and a nicol is inserted so that the direction of vibration of the rays traversing it is parallel to the same axis: then the refractive indices of light vibrating parallel to that axis of optical symmetry may be investigated by the usual methods without the confusion caused by the bifocal images described by Sorby.—L. J. Spencer: A Butterfly Twin of Gypsum. In a well-developed twin-crystal, 6 inches across, from Girgenti, Sicily, in which the twin-plane is *d* (101), the two individuals are situated on the same side of the twin-plane instead of on opposite sides as in the usual type.—Dr. W. R. Jones: The Alteration of Tourmaline. In a moist tropical climate minerals which are ordinarily regarded as stable break down to an extraordinary degree. At Gunong Bakau, Federated Malay

States, tourmaline is found more or less completely altered to a mica (probably phlogopite) and limonite, the degree of alteration decreasing with increasing depth from the surface, suggesting that the change was caused by the percolation of water from above. The freshness of tourmaline grains in sands is very probably due to the removal of the altered products by chemical and mechanical means.

III.—Geological Society of Glasgow.

Volcanoes in Ayrshire.—At a meeting of the Geological Society of Glasgow, held on March 9, Mr. G. V. Wilson, H.M. Geological Survey, read "Preliminary Notes on the Volcanic Necks of North-West Ayrshire". The area dealt with lies between Dalry, Ardrossan, and Largs, and has been found to contain the remnants of about thirty volcanoes. The various necks were described, and it was pointed out that they were not all of the same age. While some are probably of Calciferous Sandstone age and connected with the great Misty Law volcano further north, others were much later as they contained large blocks of sedimentary rocks, including one with a coal-seam which was large enough to be worked within the vent many years ago. This vent must therefore have been in action after the formation of the coals of early Carboniferous times. Fragments of charred wood also occurred, while in one instance sea-shells, which had evidently been washed from the sea-floor directly into the volcano, were found. This showed that the volcano had been either submarine or on low ground liable to submergence, and the shells being of a type not later than Millstone Grit, the age of the vent was approximately fixed thereby. It was pointed out that the ash in the necks was, in some instances, very similar to that which replaces the black-band ironstone over much of the Dalry district, which suggested that it had come from this source, and that activity had continued intermittently until Millstone Grit or later times. It was suggested that in the days of its activity this district had resembled the San Franciscan volcanic field of Arizona. The paper was illustrated by a series of photo-micrographs and views.

Mr. J. V. Harrison, B.Sc., described a section at Tormore, Arran, showing the junction of the two red rock series of Arran, and where no sharp line of division was visible.

CORRESPONDENCE.

THE GRAINSGILL GREISEN OF CARROCK FELL.

Sir,—Among a collection sent to me last year of small specimens from various well-known rocks in the British Isles was one of the Grainsgill Greisen, Carrock Fell, described in vol. li of the Q.J.G.S. by Mr. A. Harker. For purposes of comparison with local rocks I have had three sections prepared from this specimen, which was only about 1½ in. square and ½ in. thick, and used the remainder for separations in heavy liquids. The quantity of rock available was so